innovate

2014

SUSTAINING AN INNOVATIVE AND GLOBALLY COMPETITIVE FRESH FRUIT INDUSTRY

POST-HARVEST
INNOVATION PROGRAMME

Fresh fruit and people have more in common than meets the eye.
Fruit lives and breathes. It needs protection, must be handled with care and respect.
Must not be bruised or harmed and needs looking after to mature. Fruit can tell what it needs and when. It has an immune system that can be activated to fight disease. While crisscrossing the globe, fruit also needs to be kept cool.

Fruit depends on a support system of caring, innovative people who do the right things right, at the right time. Only through this value chain can it be economically productive and ultimately enjoyed around the world.

Our fresh fruit industry is a proud ambassador for South Africa.

The PHI Programme wishes to thank every person who contributed to this publication with his or her expertise, time, passion and commitment. Thanks to your dedication, *Innovate* is a true reflection of the Programme's commitment to excellence and industry advancement.

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A special word of thanks to Desireé Thompson for her valuable editorial input and advice, in her capacity as writer of the previous two PHI books, and as in-house writer and editor at the Fresh Produce Exporters' Forum (FPEF).

A warm thank you to Cyril Clarke, Cathy Dippnall, Elmarie Duvenage, Willem Law, Stephanie Niewoudt, Raine Parenzee, Sophia Prinsloo, Tisha Steyn and Gerrit van Rooyen for their contribution.

foreword

South Africa exports more than 50% of the fruit produced in the country every year. For the 2012/13 season, this amounted to 2,5 million tons of fruit. Moving such quantities of perishable produce over the vast distances that separate South African farms from markets in Europe, the United States, the Middle East, Far East and Russia, is a remarkable logistical feat. All efforts in this value chain have a common goal: delivering fruit to the consumer at the point where quality, shelf life and value for money converge.

The international trade in food is a revenue earner for governments and an important mechanism to promote global food security. According to the World Food Programme, we will have to produce the same volume of food in the next 50 years as was produced in the past 10 000 years. In addition, the food has to reach the people who need it. In the process of transporting food; waste is a challenge. Research findings for developing countries indicate that 40% of fruit and vegetables produced go to waste due to poor post-harvest storage, processing and packaging, and distribution and retail practices.

Food preservation has long been entrusted to chemical herbicides, fungicides and insecticides. However, the world's love affair with synthetic products is fast coming to an end. Increasingly, consumers are demanding that environmentally friendly practices and technologies be employed to keep pests at bay and improve fruit quality and shelf life.

Rising costs are furthermore forcing producers and exporters to rethink every link in the value chain – from input costs, choice of varieties to cultivate and orchard management, to deciding on which export markets to target. African countries, for instance, are a growing market. In 2011, around 25% of all locally produced apples were exported to the continent. Africa is a good market for some of our products, mainly because it is closer than our traditional markets in Europe.

This combination of pressures and opportunities facing the local fresh fruit industry, continues to be the driving force behind the Post-Harvest Innovation (PHI) Programme.

Through its structure of engaging government, industry, universities and other research institutions, the PHI Programme contributes to:

- Cost savings and thus affordability of fruit;
- Increased shelf life of fresh fruit, which improves availability;
- Human capacity development, particularly job creation, the retention of skills and the creation of opportunities for young and established scientists; and
- Adding value to the National Development Plan, which urges role-players to "*increase and refocus investment in research and development for the agricultural sector. Growth in agricultural production in South Africa has always been fuelled by technology and the returns on investment in agricultural research and development have been high, partly because South Africa has adapted technology from all over the world to its circumstances. This should again become the focus of agricultural research by research councils, universities and the private sector for all scales of farming.*"

Over the past seven years, the PHI Programme has spearheaded research into solutions and innovations to strengthen the post-harvest segment of the export chain. This publication highlights the results of our efforts from 2011 to 2014. We believe that these science and technology initiatives will assist in a continuous and increasingly important way to address food security.

This book intends to inspire and inform. It is about an exhilarating journey into the world of science, seeking knowledge to create understanding and invention. It gives an overview of the 24 research projects, conducted during the second phase of the Post-Harvest Innovation Programme. It is about technological advancement and transformation – the focus is post-harvest and the aim is excellence.

As is evident from the projects showcased in this publication, the PHI Programme is instrumental not only in bringing about change in the post-harvest arena, but also to extract value from those changes. Someone once said that change is slow – until you realise that it is not. The industry knows that we cannot wait for change to happen; we have to make it happen.

Let us continue on this path of change and innovation.

Anton Kruger

Anton Kruger
CEO of the Fresh Produce Exporters' Forum and Chairman of the Programme Management Unit of PHI

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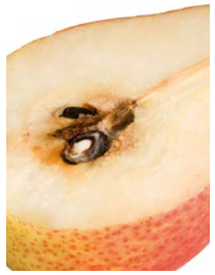


introduction

The Post-Harvest Innovation (PHI) Programme is a public-private partnership between the Department of Science and Technology (DST) and the Fresh Produce Exporters' Forum (FPEF). Its purpose is to support research and development (R&D) aimed at enhancing the global competitiveness of the South African fresh fruit export industry.

As its name indicates, the PHI Programme focuses its efforts on post-harvest technology in high-priority areas. In addition to providing a platform for R&D, it aims to build critical mass and institutional capacity to support innovation in the fresh fruit export industry.

PHI was launched in two phases between 2007 and 2013. PHI-1 and PHI-2, as the phases were called, addressed specific post-harvest technology challenges through targeted innovative R&D projects.

The Post-Harvest Innovation Programme is administered by the Fresh Produce Exporters' Forum. A dedicated programme coordinator, Junette Davids, is responsible for its day-to-day activities.

A programme management unit (PMU), which represents the industry, academia and relevant government departments, governs the PHI Programme by providing strategic guidance and performing an oversight role. Presently, the PMU consists of representatives from the Department of Science and Technology, the Department of Trade and Industry, the Department of Agriculture, Forestry and Fisheries, the Perishable Products Export Control Board, the Fresh Produce Exporters' Forum, academic researchers and an independent industry consultant.

Good news is that the DST has approved the continuation of PHI for another three years. During this period, this promising public-private partnership will be sustained and reinforced through an equal funding arrangement.

Junette Davids
PHI Programme Coordinator

Junette Davids

VISION

To transform the global competitiveness of the South African fresh fruit export industry by supporting the development of innovative technology in the post-harvest leg of the value chain.

MISSION

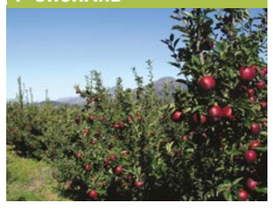
To engender a culture of innovation by providing funding opportunities to deserving applicants that will creatively seek solutions for the technology gaps identified in the fruit export value chain.

Around the world in 40 days

The South African fresh fruit supply chain is very long. From the point of picking, it can take up to 40 days before an apple, pear or bunch of grapes is in the consumer's hand. The cold chain commences the moment fruit is first cooled, as soon as possible after harvesting. Without the cold chain, exports will not be possible – fruit quality and shelf life depend on it. The entire supply chain is also a value chain. As fruit is moved along the chain, its value steadily increases along with the financial risk to the producer and exporter. The goal is always to deliver the best quality and achieve the highest return on investment.



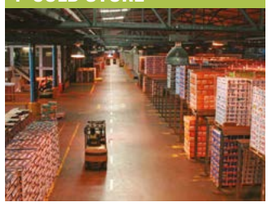

1 ORCHARD



2 PACK HOUSE

3 INSPECTION

4 COLD STORE



5 CONTAINER TRUCK

6 LOADING

7 CONTAINER SHIP

8 PORT OF IMPORT

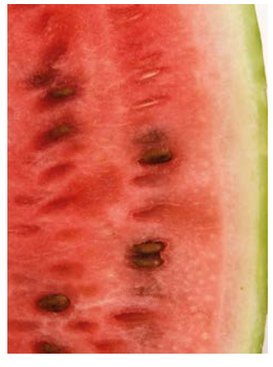
9 DISCHARGE

10 COLD STORE

11 DISTRIBUTION CENTRE

12 SUPERMARKET

13 CONSUMER



post-harvest pathology, food safety and disease control

Clean can be overkill

It is entirely possible that by sterilising fruit, producers are killing the very organisms that can protect their produce against post-harvest diseases and decay. Talk about throwing babies out with the bathwater…

The study found that bad bacteria, such as *E. coli*, *Salmonella* spp. and *Listeria monocytogenes* colonies on peaches and pears can potentially be controlled with 'good' yeasts such as *Aeromonas* spp. and many other isolated from the fruit surface.

THE PERCEPTION EXISTS that fruit with a high microbial load is of inferior quality, represents a food safety risk and is an indication of poor hygiene practices. This is all unfounded. In fact, fresh produce from the field carries its own natural microbial population that reflects the diversity and species richness typical of an ecosystem in balance. The latter is called a climax community.

Prof. Lise Korsten from the University of Pretoria's Department of Microbiology and Plant Pathology, explains that in nature, 'good' microbes usually keep the 'bad' ones under control. "Therefore, if we can determine the microbial dynamics of fresh, safe and healthy fruit, it will help us to understand how best to protect fruit against post-harvest and foodborne pathogens."

Current legislated standards and guidelines for fresh fruit are outdated and do not take new scientific data of healthy natural microbial loads into consideration. This situation places South Africa's international trade profile at risk. "The worldwide trend towards green standards should reflect new microbial ecological thinking," says Prof. Korsten. "Science develops continuously and the time has come for plant health and food safety assessments to be based on new scientific information about microbial loads that occur naturally on fresh fruit."

1 Prof. Lise Korsten and Research Coordinator, Dr Erika du Plessis.
2 Zama Zulu at work in the laboratory.

But how do we know which microbes are which and where do we draw the line between enough and too much? To help provide the answers, Prof. Korsten led a study to ultimately develop microbial threshold guidelines for the quality and safety of fresh produce in South Africa.

To achieve this aim, the study set out to:

- Establish the microbial profile and load of fresh fruit after harvesting.
- Develop the best, quickest and most suitable method to identify foodborne pathogens.
- Determine, at a post-harvest level, the potential microbial hazards of selected crops.

HOW IT WORKED

To meet the first objective of the project, peaches were sampled in the orchard, from crates at the pack house entrance and from boxes after packing, to determine the natural total microbial load on the fruit surface. Yeast numbers were similar in all three samples, while more fungi were detected on peaches from the orchard, than on pack house peaches. The counts for one of the villains, the foodborne pathogen *E. coli*, were similar in the orchard and in boxes after packing. *Enterococci* were present on the surfaces of peaches from the orchard but none were detected on peaches at the pack house entrance or after packing.

In achieving the second objective, the team compared rapid diagnostic methods. They first isolated and identified different microorganisms to provide a profile of potential high-risk pathogens. The microorganisms selected were *Eschericia coli* 0157:H7, *Listeria monocytogenes*, *Salmonella enterica* sp. enterica serovar *Typhimurium* and *Staphylococcus aureus*. In this regard, the project was a continuation of previous studies that have resulted in the development of a new pathogen database.

To meet its diagnostic method objective, the project did development work, using MALDI-TOF (matrix assisted laser ionisation – time of flight mass

HOW THE RESEARCH ADDS VALUE

The value of this project for the industry is that it:

- proposes more realistic guidelines for fresh fruit;
- develops a more effective identification system for food-borne pathogens on fresh fruit surfaces; and
- provides a microbial baseline for fresh produce.

PROJECT TITLE
The impact of post-harvest microbial dynamics on the quality and safety of fresh fruit

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DURATION
Two years

PHI-2 CONTRIBUTION
R610 236

LEAD INSTITUTION
University of Pretoria (Department of Microbiology and Plant Pathology)

BENEFICIARY
The deciduous and subtropical fruit industries

FOCUS AREA
Post-harvest pathology, food safety and disease control

HUMAN CAPITAL DEVELOPMENT
One BSc, one BSc Honours, one post-graduate and one BTech student

PRESENTATIONS AND PAPERS DELIVERED
Two

A combination of identification methods should be used to determine the presence or absence of food-borne pathogens. Although the *E. coli* levels in some of the irrigation water sources were found to be higher than the maximum of ≥1000 cfu/100ml stipulated in the irrigation water guidelines (DWAF 1996), the microbial load on fruit surfaces were much lower. This shows that a direct link between contaminated water and fruit health cannot always be made.

spectrometer) equipment and a new state-of-the-art molecular detection system called Multiplex PCR.

This part of the study proved the complexity of determining whether or not harmful bacteria are present on fruit. For example, the *Salmonella* colonies isolated on chromogenic media and considered presumptive 'baddies' were proved to be false positives when using the MALDI-TOF system. However, the MALDI-TOF could not be used to confirm the identities of the presumptive *Listeria* colonies. This was done through sequencing.

It was also found that when it came to *Escherichia coli*, *Salmonella spp*, *Staphylococcus aureus* and *Listeria spp*, selective enrichment and plating onto chromogenic selective media could not be considered a reliable method. MALDI-TOF analyses correctly identified 94% of the pathogens. The molecular detection system can determine the presence of the foodborne pathogens quicker and more accurately.

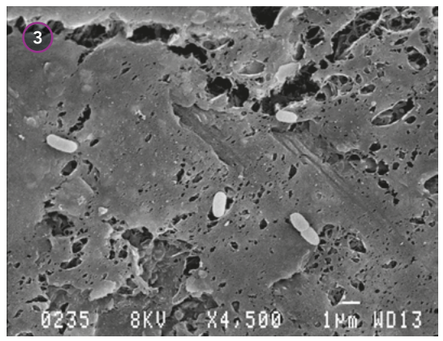
WHAT THEY FOUND

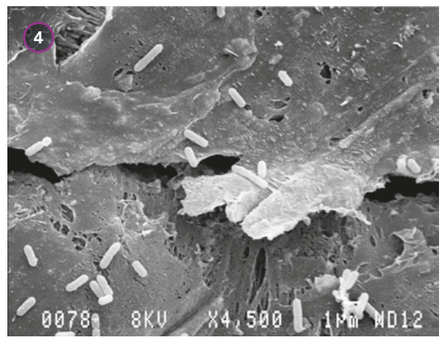
The study confirmed that the current microbial specifications used as guidelines for raw fruit and vegetables (issued by the Department of Health Directorate, Food Safety, South Africa) are not based on new scientific data of actual healthy, natural microbial loads. For example, existing microbiological specifications for raw fruit and vegetables state that there should be no *E. coli* per 1g of product. It is proposed that the guideline should rather specify 'human pathogenic' *E. coli*, since environmental, non-pathogenic *E. coli* exists everywhere in nature. This example underscores the value of the project's proposal to set more realistic guidelines for fresh fruit.

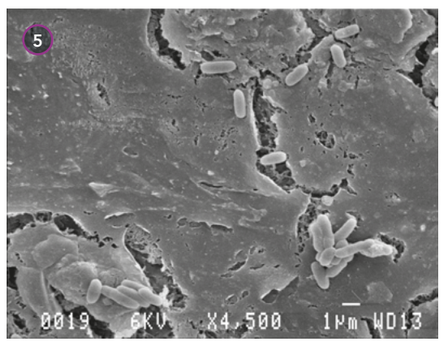
Furthermore, existing diagnostic methods are not fit for purpose, as Prof. Korsten explains. "Traditional methods that are currently used are based on selective media and provide only presumptive organisms. It is proposed that a multi-method approach be used – as was done in the study – to confirm pathogen prevalence. This will certainly benefit food safety risk management systems in the supply chain."

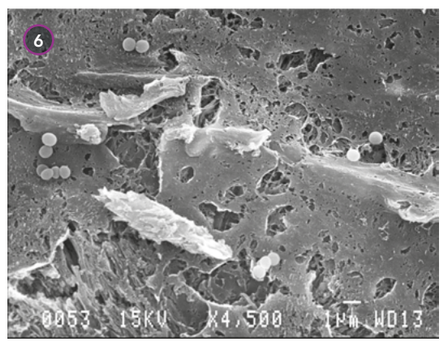
Now that the study has been completed, the data from all the trials must be compared to calculate a national average that will represent a natural microbial load on a fresh product. From there, fruit quality and safety standards and guidelines can be established for the South African fresh fruit export industry.

post-harvest pathology, food safety and disease control









1 Quinton Volschenk (BSc Honours student) and Francois Duvenage (research assistant).
2 *Salmonella enterica* on selective chromogenic media.
3-6 Scanning electron micriscopy (SEM) photos of human pathogenic microorganisms: *E coli* on pear surface [3]; *Listeria monocytogenes* on pear surface [4]; *Salmonella Typhimurium* on pear surface[5]; *Staphylococcus aureus* on pear surface [6].

Post-harvest pathology, food safety and disease control

Anoint the avocado

Thyme oil used in new-generation packaging not only keeps avocados safe from disease, it also extends their shelf life.

2014 18

The combination of thyme oil in volatile phase with MAP can maintain fruit quality for up to 18 days at market shelf by increasing the antioxidant pool in the mesocarp.

SOUTH AFRICA'S EXPORT AVOCADOS are popular for their nutritional properties, such as being rich in vitamins and high in fibre. Sadly, their shelf life is relatively short. Their quality and marketability are also much affected by anthracnose, a common post-harvest disease.

Producers have pre- and post-harvest options to combat anthracnose. Before harvesting, the fruit can be sprayed with copper oxychloride to control anthracnose. However, repeated applications throughout the season can cause a build-up of copper residues on the fruit. It can also affect the beneficial fructoplane population on the fruit surface.

Post-harvest, the synthetic fungicide, prochloraz, is commercially used to control anthracnose in South Africa, Australia and New Zealand. This option is also not without its problems. Disposal of the fungicide solution that was used for dip treatment is a major problem for commercial pack houses. Additionally, due to the development of fungicide resistant strains, post-harvest fungicide application is not considered a long-term solution for the fruit industry.

On the other hand, consumers demand attractive fruit, free of diseases and toxic residues and with a longer shelf life. Importing countries furthermore enforce strict regulations regarding the minimum residue levels allowed on the skin of the fruit.

In the past, wax coatings such as carnauba or polyethylene were commonly applied to fruit. It is essential that the wax coating does not leave any residues or influence the natural glossiness, eating quality and characteristic flavour of the fruit. The European Union (EU) does not allow morpholine in wax emulsions and can remove the application of wax for fruit such as avocado and citrus, due to increasing green consumerism and consumer demand for organic fruit.

All these factors have stimulated the search for new alternative solutions to replace fungicide application and wax coating for avocados.

ENTER ESSENTIAL OILS

The general antifungal activity of essential oils is well documented. A combination of essential oils with a commercial coating (Avoshine®) was previously recommended as an acceptable post-harvest treatment to control anthracnose in avocados. Unfortunately, the organic niche markets, specifically in developed countries, prefer fruit without coatings.

However, the vapour phase of essential oils presents viable options. It requires low concentrations and is more effective than the liquid phase application. Interestingly, it does not affect the smell and taste of foodstuff.

The vapour application requires packaging that creates an environment in which the vapour can be effective. Therefore, the application of essential oil has to be investigated in combination with modified atmosphere packaging (MAP). MAP was shown to reduce the ripening process by inhibiting the ethylene action in avocados, thereby extending their shelf life. In South Africa, the current practice is that avocados are treated with prochloraz dip fungicide and packed in Fresh Mark™ bags.

Against this backdrop, Prof. Dharini Sivakumar, from the Department of Crop Sciences at the Tshwane University of Technology (TUT), headed a Post-Harvest Innovation Programme study to investigate the effect of different essential oils – in vapour phase and at low concentration – in combination with MAP on:

- Anthracnose disease incidence and modes of action of the essential oils on decay control.
- Incidence of physiological disorders, physicochemical parameters (weight loss, firmness, colour) and sensory properties.
- Bioactive compounds and antioxidant activity, in order to determine the overall fruit quality of three commercial avocado cultivars, namely 'Hass', 'Fuerte' and 'Ryan', during domestic marketing temperature storage (10°C) for 18 days and thereafter up to 10 days at market shelf conditions of 20°C.

OUTCOME OF THE STUDY

The use of a MAP (bi-orientated) carrier bag in combination with thyme oil sachets treatment significantly reduced the incidence and the severity of anthracnose, grey pulp, vascular browning, weight loss and loss of fruit firmness. In addition, it showed acceptable taste, flavour, texture and higher overall acceptance. The total phenolic compounds, flavonoid contents and antioxidant activity, after ripening at 25°C followed by cold storage at 10°C, were also higher.

Thyme oil sachets in a MAP bag induced the activities of defence enzymes and enhanced the antioxidant enzymes, such as superoxide dismutase and catalase. These results confirm that the effects of thyme oil on anthracnose in avocados are due to the elicitation of biochemical defence responses in the fruit and inducing the activities of antioxidant enzymes.

"Thyme oil can be a cost-effective alternative to a fungicide like prochloraz," says Prof. Sivakumar. "Thymol essential oil is already used as a food preservative. The US Food and Drug Administration lists it and thyme, the herb, as food for human consumption, and recognise them as Generally Regarded as Safe (GRAS) food additives."

To transfer the new knowledge, Prof. Sivakumar held an information day at TUT for farmers, retailers, post-graduate students and researchers. They also compiled a booklet to introduce best post-harvest practices for avocados for emerging farmers.

PROJECT TITLE
Developing environmentally friendly post-harvest disease control methods for peaches and avocados

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DURATION
Two years

PHI-2 CONTRIBUTION
R285 000

LEAD INSTITUTION
Tshwane University of Technology (Department of Crop Sciences)

BENEFICIARY
The deciduous and subtropical fruit industries

FOCUS AREA
Post-harvest pathology, food safety and disease control

HUMAN CAPITAL DEVELOPMENT
Two MTech and two post-doctoral students

PRESENTATIONS AND PAPERS DELIVERED
One

PUBLICATIONS
Four

1 Prof. Dharini Sivakumar.
2 Avocados infected with anthracnose disease.

Essential oils and their components are attracting increasing interest due to their natural origin, volatility, relatively safe status, low risk of developing resistance in decay-causing pathogens, wide acceptance by consumers, and eco-friendly and biodegradable properties.

MORE POWER TO THE PEACH

Post-harvest diseases such as grey mould rot, blue mould rot, Rhizopus rot and brown rot affect the shelf life, fruit quality and marketability of South Africa's export peaches. Some pack houses use a synthetic fungicide (Rovral®) to control post-harvest decay, which may increase up to 50% without treatment.

The use of synthetic fungicides to treat peaches is subject to the same challenges as in the case of avocados. In addition, synthetic fungicides are expensive for small-scale farmers and peaches are not recommended for aqueous sanitation. The application of physical treatments, such as hot water and vapour heat, consumes a lot of energy and requires costly equipment.

For these reasons, there is an urgency to find new alternatives to synthetic fungicides and to improve the technologies that will extend shelf life. Novel technologies, such as adding essential oils as active agents inside the packaging, wax coatings, edible coatings, edible films or active labels have shown promising results. Peaches, however, are not subjected to waxing in the packing line.

Application of nanotechnology in food packaging has been shown to extend the shelf life of food products. Incorporating nanoparticles in films has been proven to provide protection against microbial decay due to their improved antimicrobial properties, thereby altering surface wettability and hydrophobicity of the films.

The fresh produce industry prefers to replace petrochemical-based films with films made of biodegradable, environmentally friendly materials. The biodegradable films are made from natural biopolymers such as chitosan, starch, proteins, corn and whey proteins. The antimicrobial property of chitosan film was reported to improve with oregano essential oils and thyme oil. Nanocrystalline boehmite alumina n-AlO(OH) has been reported to improve the mechanical properties of synthetic films, such as low- and high-density polyethylene. Antimicrobial activity of alumina (Al_2O_3) nanoparticles was reported against human and foodborne pathogens for clinical application.

Based on these previous findings, the researchers set out to study the effect of chitosan lidding film and thyme oil sachets, chitosan lidding film incorporated with (1%) boehmite alumina nanoparticles and thyme oil sachets on the incidence and severity of post-harvest diseases and changes in fruit quality and biochemical parameters in peaches packed in a polyethylene terephthalate (PET) punnet and stored at 0,5°C, 90% RH for seven days and thereafter held at simulated market shelf conditions for five days at 15°C, 75% RH.

OUTCOME

Chitosan lidding film and thyme oil sachets teatment maintained 56,43% thymol and 38,7% caryophyllene (head space volatiles) within the punnet, while the active ingedients of thyme oil vapour were moderately lower within the head space of chitosan film-boehmite alumina and thyme oil sachets treatment. Chitosan film-boehmite alumina lidding film and thyme oil sachets treatment maintained a slightly higher O_2/CO_2 ratio (head space gases) than the chitosan film and thyme oil sachet treatment. Chitosan film-boehmite alumina lidding film demonstrated an increased water vapour transmission rate to the chitosan lidding film. The chitosan lidding film and thyme oil sachets treatment or chitosan film-boehmite alumina lidding film and thyme oil sachets treatment delayed colour changes and maintained the SSC/TA, ascorbic acid content, total phenolic compounds, and antioxidant activity during post-harvest storage. Panellists preferred fruit from chitosan boehmite alumina lidding film and thyme oil treatment.

The results suggest that the combination of chitosan lidding film and thyme oil sachets can be recommended as a suitable post-harvest treatment due to its effectiveness in controlling post-harvest diseases and retaining fruit quality and sensory properties, notably the peach aroma.


1

Post-harvest pathology, food safety and disease control

Results suggest that chitosan lidding film and thyme oil sachets can be a suitable treatment in controlling post-harvest diseases.


2


3


4

1 Dr Shittu worked as a post-doctoral student on the peach project.
2 Bevly Mampolo and Dr PS Sellamuttu with the GC/MS (gas chromatography and mass spectrometry) equipment used in the study.
3 Decayed peaches cause substantial losses in the post-harvest value chain.
4 Researchers busy preparing peaches for the artificial inoculation trails.

Mitigation Technologies for Sanitary and Phytosanitary Compliance

Can't breathe, can't breed

Chemicals are no longer fruit producers' only defense against pests. By creating conditions under which no insect can survive, new treatments are green and lethal.

FRUIT-PRODUCING COUNTRIES that supply phytosanitary markets have to make sure that fruit is all they export. The risk of introducing insect pests into countries where they do not occur naturally has to be avoided. In this quest, pre-harvest measures such as orchard sanitation are important, but post-harvest mitigation treatments are critical.

Since the 1930s, methyl bromide fumigation has been used worldwide as a broad-spectrum and fast-acting mitigation treatment. However, scientists have since discovered that methyl bromide depletes the ozone and in 1992 a global phase-out plan was launched. As of 2005, developed countries were banned from using the product. Developing countries, including South Africa, received an extension and are permitted to use methyl bromide for quarantine purposes until 2015.

1 Dr Shelley Johnson.
2 While the core temperature of the fruit is monitored, the air around the fruit reaches a maximum of 40°C. One objective of this project is to determine how the heat impacts the ripening of fruit. Another is to establish whether the most opportune time to treat fruit destined for the export market is, in fact, just before cold storage.

In addition to this looming deadline, the South African fresh fruit export industry is under increasing international pressure to reduce its general use of chemicals. Alternatives that are currently being explored include irradiation and treatments that combine extreme temperatures with modified controlled atmosphere. Irradiation is a processing technique that exposes food to electron beams, X-rays or gamma rays. The process produces a similar effect to pasteurisation, cooking or other forms of heat treatment, but with less effect on look and texture.

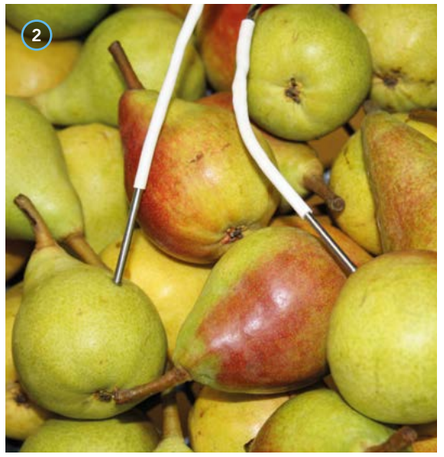
KNOCKOUT COMBINATION

A combination treatment that is now becoming available in South Africa, is known as controlled atmosphere temperature treatment system, or CATTS. It combines two stresses to kill insects, namely heat and an atmosphere with low oxygen and raised carbon dioxide levels that impair breathing.

Dr Shelley Johnson, who works for HORTGRO[Science], is currently leading a new project that evaluates the viability of this environmentally friendly post-harvest mitigation treatment. Her research is focused on the control of three prominent South African phytosanitary insect species, namely false codling moth, banded fruit weevil and grain chinch bug. Stone and pome fruit varieties were selected for the trials. Trials will also be conducted for citrus and subtropical fruit.

The cornerstone of the project is a laboratory-sized CATTS unit, supplied by Techni-Systems in the USA. The Post-Harvest Innovation Programme financed the purchase of the unit and HORTGRO[Science] funded a Techni-Systems technician to install the machine and train the research team on its use and maintenance. The CATTS unit arrived in South Africa in July 2013 and was installed at the Department of Conservation, Ecology and Entomology of Stellenbosch University, where Dr Johnson is based as a research associate.

Dr Johnson first became aware of CATTS technology while researching alternative phytosanitary treatments. She contacted Dr Lisa Neven, the research entomologist at the United States Department of Agriculture (USDA) Agricultural Research Service (ARS) in Washington State, who led the team that developed the first CATTS unit on a laboratory scale, for help. Their collaboration has since seen the publication of two scientific articles in the *Journal of Economic Entomology*. Dr Johnson recently visited Dr Neven to investigate the large-scale CATTS treatments that are now available thanks to the use of a commercial unit with two-ton chambers.



THE CATTS STORY

CATTS technology was developed by the United States Department of Agriculture (USDA) Agricultural Research Service (ARS) in Washington State, after experimentation with thermal treatments in combination with controlled atmosphere (CA). Forced-air is used at high temperature and the CA environment is made up of low oxygen levels and raised carbon dioxide levels.

Despite the success of the two-pronged treatment, the initial tests took very long to complete, especially with infested fruit. To hasten the process and avoid the expense of in-fruit treatments, the USDA-ARS researchers replaced the forced-air with hot water. The result was the controlled atmosphere water bath (CAWB). A large number of insects can be tested with the CAWB and it can indicate the heat tolerance and potential response of insects to CATTS.

Post-harvest treatments have been developed in the USA to control codling moth and western cherry fruit fly in cherries, and codling moth and oriental fruit moth in apples, peaches and nectarines. Fruit quality evaluations have shown that these treatments are not detrimental to fruit marketability.

CATTS treatments are now listed in the USDA-APHIS (Animal and Plant Health Inspection Service) Quarantine Treatment Manual, specifically approved for the control of insect pests in fruit exported from the USA.

PROJECT TITLE
Controlled Atmosphere Temperature Treatment System (CATTS) as a post-harvest treatment for phytosanitary pests of deciduous fruit

PRINCIPAL INVESTIGATOR
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DURATION
Twenty-seven months

PHI-2 CONTRIBUTION
R400 000

LEAD INSTITUTION
HORTGRO[Science] and Stellenbosch University (Department of Conservation, Ecology and Entomology)

BENEFICIARY
The citrus, deciduous and subtropical fruit industries

FOCUS AREA
Mitigation technologies for sanitary and phytosanitary compliance

HUMAN CAPITAL DEVELOPMENT
One MSc student

Mitigation Technologies for Sanitary and Phytosanitary Compliance

> "The advantage of CATTS as a combination treatment is that it kills insects faster and the reduced treatment times help to maintain fruit quality."
> Dr Shelley Johnson

THE RESEARCH PROCESS

In preparation for the South African CATTS project, the research team conducted preliminary studies in warm fruit baths to evaluate the effect of heated controlled atmosphere post-harvest treatments on key phytosanitary insect pests in the South African deciduous fruit industry, and to determine for which species CATTS technology is a feasible post-harvest mitigation option. The preliminary water bath studies focused on false codling moth, banded fruit weevil and grain chinch bug. Tests were conducted on adult banded fruit weevil and grain chinch bug, while different larval and egg stages of false codling moth were used. The temperatures and duration of thermal treatments needed to kill the pest species, were recorded.

A post-graduate student is currently testing the responses of fruit fly and mealybug to water bath treatments. Test temperatures range between 23°C and 45°C.

With the arrival of the CATTS unit, studies can now be carried out on infested fruit. Tests are repeated on false codling moth, banded fruit weevil and grain chinch bug, fruit flies and mealybugs to confirm treatment times and efficacy, and evaluate fruit quality after treatment.


1

In terms of the controlled atmosphere part of the treatment, Dr Johnson uses 1% oxygen, 15% CO_2 and nitrogen as the balance, in the current study.

"Heat is obviously an issue with fruit quality," says Dr Johnson. "The question is what the high temperatures will do to the fruit, even though intense heat will not necessarily be applied for a long period. The challenge is to find an ideal balance between heating rate and duration."

To help answer these questions, fruit quality tests will be conducted in collaboration with the Department of Horticultural Science of Stellenbosch University in the final phase of the project. In order to properly establish the effect of the treatment on the fruit, the intention is to use larger fruit quantities than the water bath system could accommodate.

"If our study proves that CATTS treatments can successfully control South African quarantine pests without impacting negatively on fruit quality, it is likely that a commercial CATTS unit will be manufactured in South Africa," says Dr Johnson.

It is not difficult to engineer, since the main difference between a laboratory-scale unit and a commercial model is the size of the chamber. The simplicity of the engineering, however, does not detract from the major contribution that commercial-scale CATTS treatments can make to South Africa's access to phytosanitary export markets.


2


3

1 The controlled atmosphere temperature treatment system (CATTS) combines two stresses to kill insects, namely heat and a modified atmosphere with low oxygen and raised carbon dioxide levels that impair breathing.
2 From the top: a false codling moth; a grain chinch bug; a long-tailed mealybug.
3 The modified atmosphere inside the CATTS unit is created by combining carbon dioxide, nitrogen and air. Nitrogen controls the concentration of O_2, which causes respiratory stress in the insects. Turning up the heat while lowering oxygen levels makes breathing impossible for insects.

Mitigation Technologies for Sanitary and Phytosanitary Compliance

SA plums head for the Big Apple

Thanks to a successful partnership between gamma rays and insect barrier bags, a greater variety of local plums could soon be welcome in the United States.

As a result of this work, the option to export more plum cultivars from South Africa to America is now a real possibility.

IN AD 541-542, the so-called Plague of Justinian killed thousands upon thousands of people in the Eastern Roman Empire. It all started when the Emperor Justinian imported vast volumes of grain from Egypt to feed his people. The ships that docked in Constantinople off-loaded more than food…

Food safety has improved immeasurably since Justinian's days, but concerns around inadvertently importing pests and diseases along with boxes of juicy table grapes or fragrant pears remain. As a result, countries impose strict phytosanitary regulations on fruit exporters. These are government regulations that restrict or forbid the importation of certain plant species, or their products, to prevent the introduction or spread of plant pests or pathogens that these plants may be carrying.

Cold sterilisation is an example of a phytosanitary regulation. Currently, South Africa can export some plum cultivars to the USA, but only if a cold sterilisation treatment can be strictly maintained. The requirement is uninterrupted storage at -0,5°C for three weeks. This treatment is unfortunately too harsh for some plum cultivars and may cause chilling injury that shows up as internal flesh browning.

IRRADIATION AS AN OPTION

The United States Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS) is responsible for the control of phytosanitary pests on fruit entering the USA. When the authority published legislation some years ago that allowed the importation of fruit treated by low-dose gamma irradiation, it gave exporters an alternative to cold sterilisation.

Gamma irradiation sterilises insects, thereby providing an alternative to cold sterilisation and methyl bromide fumigation mitigation treatments.

In 2004, South Africa started exploring irradiation as a feasible alternative mitigation treatment for locally produced table grapes at the Hepro Cape irradiation facility. Hepro Cape has been operating for the past 20 years in Montague Gardens, Cape Town. The business provides high-energy processing for the sterilisation of disposable medical equipment and the treatment of imported garlic and spices. It can also handle pallet loads of fruit.

Before Hepro's facilities could start playing a role in fruit exports, it had to be approved by the USDA. This involved a long process of inter-governmental agreements, facility design, operational work plan evaluation and table grape quality research. Through the combined efforts of the South African Table Grape industry, HORTGRO^{Science}, the research organisation ExperiCo Agri Science, the Department of Agriculture, Forestry and Fisheries (DAFF) and Hepro Cape, the facility received APHIS certification from the USDA in 2011. Hepro Cape is the first APHIS-certified facility in the Southern Hemisphere.

A year later, the first irradiated table grapes left South Africa for the US market – a significant development towards creating additional market potential for the South African fresh fruit export industry.

THE PLAN WITH PLUMS

USDA-APHIS approval is fruit-specific. Every type of fruit has to receive its own agreements, approved facilities, protocols and certification of packaging formats. Table grape approval therefore did not mean that all other South African exports had been cleared for irradiation.

Based on the grape success, the Innovation Programme and HORTGRO^{Science} co-financed a project

MORE ABOUT FOOD IRRADIATION

Food irradiation is a processing technique that exposes food to high-energy rays. The process produces a similar effect to pasteurisation, cooking or other forms of heat treatment, but with less effect on look and texture. Gamma irradiated food has been exposed to radioactivity but does not become radioactive itself.

Food absorbs energy when it is exposed to irradiation. The amount of energy absorbed, or the absorbed dose, is measured in units called Gray (Gy).

The energy absorbed by the food causes the formation of short-lived molecules known as free radicals, which kill bacteria that cause food poisoning. They can also delay fruit ripening and help stop vegetables, such as potatoes and onions, from sprouting.

Scientists have been experimenting with irradiation as a method of food preservation since 1950. They have found irradiation to be a controlled and very predictable process.

Food irradiation is currently permitted by over 50 countries, and the volume of food treated is estimated to exceed 500 000 metric tons annually, worldwide.

In a variety of product-specific applications, irradiation is most useful for:

- Preservation. It destroys or inactivates organisms that cause foodstuff to spoil, thereby extending their shelf life.
- Sterilisation.
- Control of sprouting, ripening and insect damage.
- Control of foodborne illnesses.

The effects of irradiation on food, and on animals and people eating irradiated food, have been studied extensively for more than 40 years.

Sources: Iowa State University website (http://www.extension.iastate.edu/foodsafety/irradiation/); Wikipedia; www.food.gov.uk

PROJECT TITLE
Certification of plum packaging formats for export of South African fruit to markets that accept irradiation in combination with insect barrier bags, as mitigation treatment

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DURATION
Two years

PHI-2 CONTRIBUTION
R397 667

LEAD INSTITUTION
ExperiCo Agri Science

BENEFICIARY
The deciduous fruit industry

FOCUS AREA
Mitigation technologies for sanitary and phytosanitary compliance

PRESENTATIONS AND PAPERS DELIVERED
Three

Food irradiation is currently permitted by over 50 countries, and the volume of food treated is estimated to exceed 500 000 metric tons annually, worldwide.

to obtain USDA certification of irradiation technology for export plums. The project was a collaborative effort between ExperiCo Agri Science and Hepro Cape.

The ExperiCo research team, led by Dawie Moelich, conducted plum fruit quality and packaging tests and coordinated the research project. The Hepro facility was responsible for the dosimetry trials in conjunction with APHIS. Dosimetry tests are done to measure the irradiation dosage and whether the limitations as set by USDA-APHIS and the US Food and Drug Administration are met. The tests have to be done on actual pallet stacks of fruit, per packaging format and according to each kind of fruit.

The plum study involved more than just determining the effectiveness of irradiation. Mr Moelich explains that, since gamma irradiation does not leave any residue on the fruit, insect re-infestation is a possibility. "We therefore had to include insect barrier packaging in our study and determine the impact of the combination of irradiation and micro-perforated insect barrier bags on the post-storage quality of plums."

APHIS regulations stipulate that the pores in insect barrier bags should not be bigger than 0,6mm in diameter and that the barrier must not influence the regular oxygen and carbon dioxide levels surrounding the fruit. Because the insect barrier bags should avoid

atmosphere modification, commercially available modified atmosphere packaging (MAP) could not be used. To complicate matters, the research team discovered that the insect barrier material was not manufactured on a large scale, locally or internationally, because of the specific pore size requirement. "Our solution was to involve a South African manufacturer to produce the packaging we needed," says Mr Moelich.

The plum cultivars used in the study were 'Songold', 'Laetitia' and 'African Delight'. Before irradiation at Hepro, the fruit was packed in the newly developed insect barrier bags and in standard commercial packaging, inside 400 x 300 x 118mm cartons.

Sub-treatments of the 'Songold' and 'African Delight' plums were also subjected to SmartFresh™, an ethylene receptor blocking technology, prior to irradiation. SmartFresh™ was applied to the plums after being stored for five days at -0,5°C and the fruit was irradiated at Hepro after six days at -0,5°C. Both the SmartFresh™ and irradiation treatments were therefore applied to the different fruit lots within one week of being harvested.

The post-storage quality was evaluated after the cultivar-specific commercial export protocols were simulated at the ExperiCo experimental cold storage facility.

THE RESULTS

One of the study's main findings was that SmartFresh™ can control the risk of internal disorders associated with the irradiation treatment and the insect barrier bag, especially in 'Songold' plums.

A further exciting result was that USDA-APHIS has accepted the locally designed and manufactured insect

Mitigation Technologies for Sanitary and Phytosanitary Compliance

barrier bag. "As a result of this work, the option to export irradiated South African plums to America, which is considered a special phytosanitary market, is now a real possibility," says Mr Moelich.

The dosimetry recorded at the Hepro Cape facility during December 2013, using mini-pallets according to the commercial stacking patterns, indicated conformance to the APHIS requirements and the data will soon be submitted to the USDA, via DAFF, for approval.

The abovementioned successes are likely to pave the way for local fruit to be exported to other markets that accept irradiation.

At Hepro fruit is exposed to the energy emitted by encapsulated cobalt-60 to sterilise fruit flies and other insects. As such, the dosages are extremely low. Much higher dosages are needed to treat bacterial or fungal infections.

1 Dawie Moelich.
2 An 'African Delight' plum ready to be picked.
3 Gamma irradiation kills fruit flies that may be present on the plums when they are harvested.
4 Left: Plums packed in an insect barrier bag inside a 400 x 300mm carton. Right: Plums in punnets, enclosed in an insect barrier bag, inside a 600 x 400mm carton.

Post-harvest Physiology and Non-destructive Fruit Quality Assessment Techniques

The secret's in the cells

Unlike beauty that is skin-deep, mealiness in pears develops at cellular level. This could be the secret to spotting mealied 'Forelle' pears before they reach the consumer.

The development of mealiness is a pre-existing condition in some 'Forelle' pears.

ONE OF LIFE'S DISAPPOINTMENTS is to bite into a fine-looking pear and instead of the moist, crisp juiciness you were expecting, you have a mouthful of soft, dry and mealy flesh!

It is this kind of experience that makes consumers think twice when buying fruit, and one that lands commercial pack houses in hot water. Every year, carton upon carton of mealy pears are turned down, leaving pack houses to pick up the tab.

'Forelle' pears are particularly prone to mealiness, especially when they are not stored under cold enough temperatures for long enough. The mealiness is usually at its worst after six to eight weeks of cold storage at -0,5°C and ripening. As the pears become less mealy the longer they are stored, the industry prescribes a mandatory cold storage period of about 12 weeks at -0,5°C for all export and locally marketed pears.

This, however, can be a logistical challenge at the best of times. Such a long storage period influences market availability and the commercial success of South African pears, as it leads to our fruit reaching the European markets after exports from Argentina, Chile, New Zealand, Brazil and Australia. More frustratingly, extended cold storage still does not guarantee that consumers will have an enjoyable eating experience.

Until recently, the only way to test for mealiness was to cut open a sample of fruit after the pears have ripened.

TAKING A CUE FROM APPLES

Are long storage periods actually the answer to curb mealiness in 'Forelle' pears? Can mealiness be detected without having to sacrifice any fruit? Is it a pre-existing condition, or does it develop because of the wrong storage conditions?

To answer these questions, enter Dr Elke Crouch of the Department of Horticultural Science at Stellenbosch University, an expert in the study of cell walls. Dr Crouch took her cue from research on apples. This work has showed that textural disorders, like mealiness, are related to cell size and shape and to the calcium that glues the cells together in the middle lamella.

Research into mealiness started in 2011 with support from the export company, Tru-Cape Fruit Marketing (Pty) Ltd, and was jointly financed by the Post-Harvest Innovation Programme and HORTGRO^{Science}.

The questions did not only interest Dr Crouch on a purely academic level. She also wanted to find a practical and non-invasive way to detect a predisposition for mealiness in pears without damaging the fruit. Her choice fell on near-infrared (NIR) technology and X-ray computed tomography (X-ray CT) scanning methods.

"Mealiness and other internal defects can potentially be detected based on the fruit's ability to absorb infrared radiation or X-rays," explains Tavagwisa Muziri, who has devoted his PhD studies in horticultural science at Stellenbosch University to the subject.

NIR spectroscopy works with the ability of radiation to interact with matter, and is based on molecular overtone and combination vibrations. It is possible to test a sample of up to 1cm thick. Although not a particularly sensitive technique, NIR can be useful in probing bulk material with little or no sample preparation. In turn, X-ray CT scanning uses a movable X-ray source and detector assembly to accumulate data from more than a hundred thin digital slices of the sample material.

It has been known since 1999 that X-ray computed tomography can be used to monitor internal changes in fruit. "Because no single technology has yet been developed to cover all current and future applications in production, storage and retail of fresh produce, we tried to synergise efforts to develop ideal quality determination techniques," says Mr Muziri.

SHEDDING LIGHT

Following detailed laboratory analyses coupled with fieldwork that linked pre-harvest effect with post-harvest quality, the research team established that mealiness is a pre-existing condition in some 'Forelle' pears.

Other findings that shed light on the pear conundrum include:

- Mealiness development starts in the neck and extends downwards through the flesh of the fruit.

'FORELLE' PEARS IN FOCUS

This smallish pear has a distinctively sweet aroma and taste. Its characteristic red freckles sets this variety apart.

Together with 'Packam's Triumph', 'Forelle' pears are the second most produced pear in South Africa per volume. In 2012, more than 3 000ha were planted with 'Forelle' pears in South Africa.

Almost three million cartons were exported in 2012.

1 A mealy 'Forelle' pear does not release juice when squeezed. When the mealy tissue is chewed, no juice will be released either. There is still no mechanism or instrument for detecting mealiness in intact fruit. All mealiness determinations are done by the mouth / taste (organoleptically) or visually by squeezing wedges of tissue – both destructive techniques.

PROJECT TITLE
Shedding light on mealiness in 'Forelle' pears

PRINCIPAL INVESTIGATOR
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DURATION
Two years

PHI-2 CONTRIBUTION
R241 284

LEAD INSTITUTION
Stellenbosch University (Department of Horticultural Science) and Tru-Cape Fruit Marketing (Pty) Ltd

BENEFICIARY
The deciduous fruit industry

FOCUS AREA
Post-harvest treatments and fruit quality disorders

HUMAN CAPITAL DEVELOPMENT
One PhD student

PRESENTATIONS AND PAPERS DELIVERED
Six

X-ray CT scanning is currently only available for experimental purposes in the fruit industry. The wood industry has already shown that it can be applied on a large scale.

- Its development is associated with larger-celled fruit and highly porous fruit with large air spaces around the cells.
- In 'Forelle', mealiness development seems to be linked to a high total soluble sugar content.
- It is possible to accurately determine the total soluble solids (TSS) in fruit with the help of non-destructive NIR spectroscopy methods. Based on the TSS, a non-destructive mealiness model can be developed.
- Such a TSS-based model is more accurate on the sun-exposed side and the neck area of the fruit.
- NIR can also be used to non-destructively detect mealiness immediately after fruit is taken out of cold storage. This means that pears can be sorted before they reach the consumer.
- X-ray computed tomography can detect mealiness either after harvest, cold storage or when the condition is fully developed. The air spaces in the fruit, which differ in volume and number between healthy and mealy fruit, are the clues.
- This technique could be developed further to measure mealiness at harvest, after storage and after ripening.


1


2

THE WAY FORWARD

Despite the insights gained, questions that still baffle the researchers include:

- Do some bearing positions produce more mealy fruit than others?
- Could the findings be of value for the 1-MCP (SmartFresh™) 'Forelle' Early Market Access programme where mealiness/ripening is inhibited from developing, and where the remainder of the fruit could be used in ripening programmes where mealiness will not be an issue?

Dr Crouch hopes that their findings that larger cells facilitate the development of mealiness will guide producers to adopt practices that result in firmer and more compact fruit. Also, she believes their research will eventually lead to technologies that can grade fruit for mealiness development at wholesale dispatch points, prior to shipment or before it reaches the consumer.

"These efforts are bound to improve the competitiveness of the producer, reduce claims and increase export volumes and income," she adds.

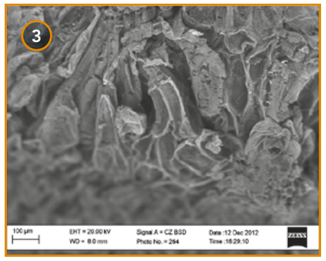
Putting these into practice is still a challenge.

"NIR grading is already used sporadically in the industry," says Dr Crouch. "To test if our model can accurately determine mealiness and TSS on a large scale, we will need to recalibrate the machines in use over the course of a few seasons and then on a commercial scale."

X-ray CT scanning is currently only available for experimental purposes in the fruit industry. The wood industry has already shown that it can be used to sort wood on a large scale.

"As data processing capabilities increase, it will become possible to process the immense volumes of information gathered by the X-ray CT scanning of fruit on a larger scale," says Dr Crouch. She believes that such technology may become par for the course on sorting lines in the next five to ten years.

Post-harvest Physiology and Non-destructive Fruit Quality Assessment Techniques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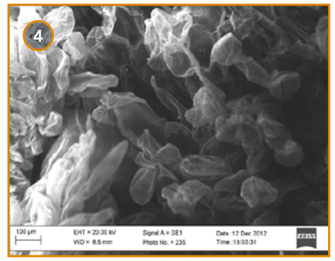
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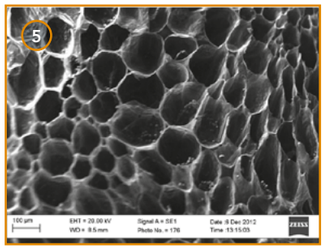
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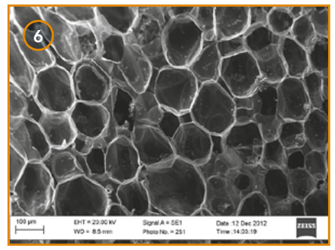
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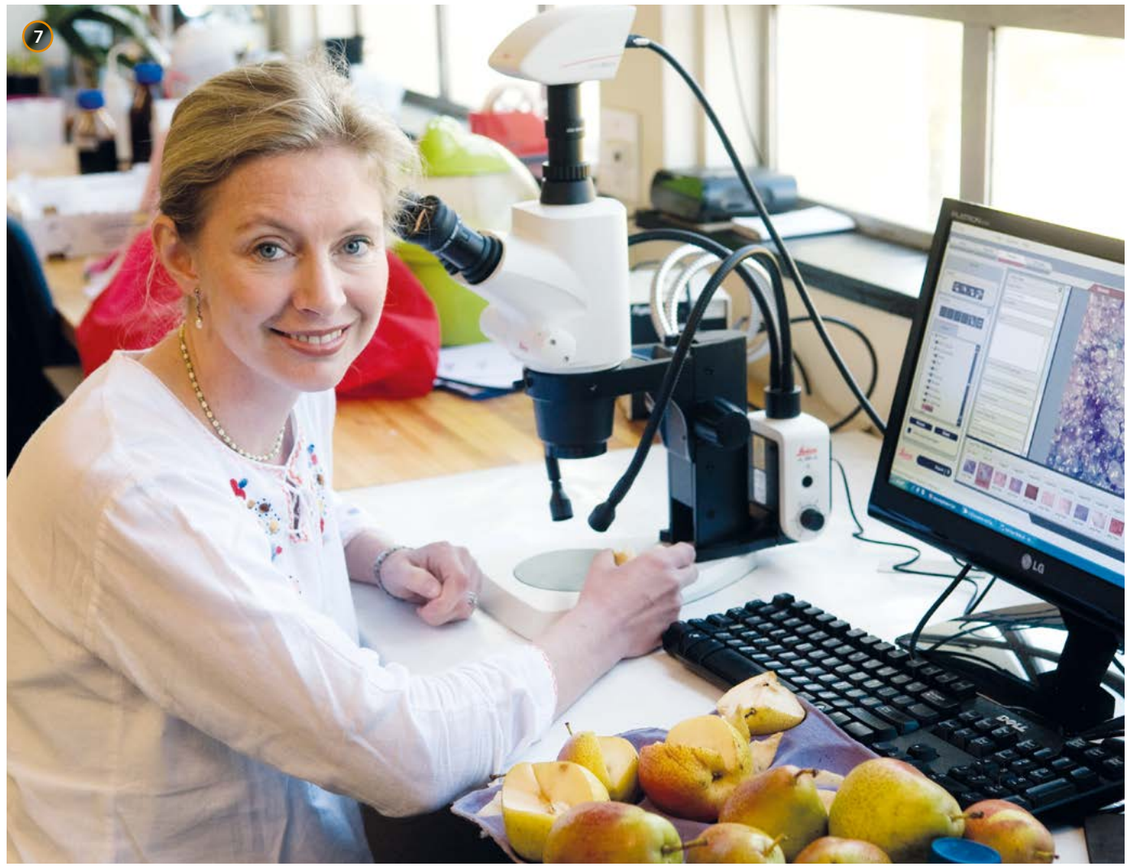
1 Dr Elke Crouch and Tavagwisa Muziri.
2 Tavagwisa Muziri uses NIR technology, a practical way to detect a predisposition for mealiness without damaging the fruit.
3-4 Scanning electron micrographs of non-mealy fruit cells [3], mealy fruit cells [4]. Non-mealy fruit cells show breakage in the cell walls, which is absent in mealy cells.
5-6 Images taken at 100x magnification: the cells are closely packed with small intercellular spaces [5]; the cells have relatively larger intercellular spaces [6].
7 Dr Elke Crouch.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Post-harvest Physiology and Non-destructive Fruit Quality Assessment Techniques

Learning exotic ways

Persimmon, or Sharon Fruit, is an ancient delicacy that only recently found its way to South African orchards and taste buds. New research is shedding light on how this fruit should be handled.

WHEN IS THE BEST TIME to pick 'Triumph' persimmons, marketed as Sharon Fruit, in order to maximise export potential? Should the fruit on the tree be light yellow or deep orange? How does the fruit respond to storage at different levels of maturity?

Knowing the answers to these questions is important in ensuring Sharon Fruit from South Africa reach their destination markets in the best possible condition. But, given that persimmons have been cultivated locally for less than two decades, there is much we don't know about them yet. One such unknown is the post-harvest quality of the fruit.

Given the great distances involved in the export industry, it is imperative that the fruit be stored and packaged under optimum conditions. At the moment, the fruit is often spoilt when it arrives at its export destination. Incorrect storage and handling practices result in excessive water loss, a decrease of total soluble solids (TSS) – which is an indication of sugars present in the fruit – loss of vitamin C and a decrease in firmness. When spoils occur, the fruit has to be repackaged at the export destination – with the farmer in South Africa responsible for the cost.

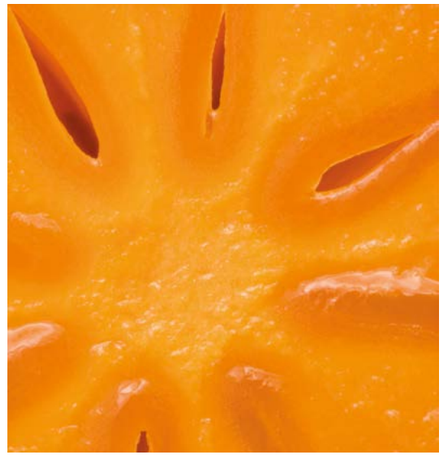
Such losses and their financial and reputational impacts gave rise to a study into the maturity development, storage and shelf life of persimmons. The research project was a collaboration between the Sharon Growers Group and the Department of Horticultural Science at Stellenbosch University (SU). The SU project leader was Dr Elke Crouch who, together with Dr Wiehann Steyn, supervised the Master's student, Pesanai Zanamwe, who did the research. The project coordinator was Ferdie Ungerer, a former technical manager of the Sharon Growers Group.

1 A close-up of a young, developing persimmon.

PICK YOUR PICKING TIME

Mr Ungerer explains that the harvesting season of Sharon Fruit stretches from the first week of April in the earlier regions to the first week of June in the late regions. Two parameters determine maturity, namely colour and firmness of the fruit.

The research project entailed three trials over a three-year period during which Cultar-treated and untreated fruit were harvested from both early and late orchards. Cultar is an agrochemical that controls vegetative growth in fruit trees.



PERSIMMONS IN SOUTH AFRICA

Although persimmons have been enjoyed in countries such as China and Japan since ancient times, it has only been commercially cultivated in South Africa since 1998. Here, they are still regarded as an exotic fruit and many South Africans are yet to taste one.

Currently, more or less 400ha of persimmons are under cultivation in the Western Cape. This yields an annual harvest of between 5 000 and 6 000 tons of fruit, of which 1 000 tons are sold locally. Most of the fruit is destined for export markets, the largest being Germany. South Africa also exports persimmons to other European countries, Singapore, Canada, Thailand and Malaysia.

PROJECT TITLE
Reducing post-harvest losses of 'Triumph' persimmons

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DURATION
Two years

PHI-2 CONTRIBUTION
R224 545

LEAD INSTITUTION
Stellenbosch University (Department of Horticultural Science) and the Sharon Growers Group

BENEFICIARY
The persimmon industry

FOCUS AREA
Post-harvest physiology and non-destructive fruit quality assessment techniques

HUMAN CAPITAL DEVELOPMENT
One MSc student

PRESENTATIONS AND PAPERS DELIVERED
Three

Persimmons are an everyday part of the Chinese diet and farmers there grow them solely for local use.

The objectives were to:

- Determine the production window that yields fruit that store better.
- Establish stages of maturity, using a colour chart, in order to harvest Cultar-induced early, naturally early and naturally late crops without affecting post-harvest life.
- Establish the effectiveness of Sinclair and near-infrared (NIR) technology as non-destructive sorting tools.

Four early and four late orchards, as well as four orchards treated with Cultar were surveyed. Fruit was harvested in four colour groups of maturity. Group 1 fell in the colour chart value 2 (dark orange, very ripe); group 2 in colour chart value 3 – 4 (lighter orange); group 3 in chart value 5 – 6 (dark yellow) and group 4 in colour chart value 7 (very light yellow, just ripe).

Size and weight measurements were taken by electronic balance and a diameter-electronic calliper, while firmness was determined by using a plunger. The NIR and Sinclair measurements were taken in the same positions as those for firmness. Soft fruit percentage was determined by finger pressing and fruit damage was visually assessed.

The fruit was assessed at harvest, after six-and-a-half weeks of storage at -0,5°C, after four weeks at 20°C and during simulated shelf life. The results were correlated with colour charts.

1 Pesanai Zanamwe, Dr Elke Crouch and Ferdie Ungerer show the colour chart that can be used during persimmon harvesting.
2 Pesanai Zanamwe, Master's student at the Department of Horticultural Science at Stellenbosch, uses NIR technology to detect the grade of ripeness of persimmons.

TRY THEM – THEY'RE GOOD FOR YOU

Persimmon is considered a nutraceutical* fruit because it contains high concentrations of carotenoids and polyphenols. Humans get carotenoids only from food and we need them for their antioxidant powers.

Research furthermore suggests that persimmons can help reduce high blood pressure and that they have antibacterial effects.

For more information on persimmons, visit www.sharon-fruit.com.

**The word nutraceutical is a combination of 'nutrition' and 'pharmaceutical' and refers to food or food products that provide health and medical benefits, including the prevention and treatment of disease.*

Post-harvest Physiology and Non-destructive Fruit Quality Assessment Techniques

THE RESULTS

It was found that in late regions the fruit firmness, soft fruit percentage, TSS and titratable acidity (TA) were better that in Cultar-treated early regions.

Darker fruit (in colour group 2) were softer and had more visible damage than fruit harvested in the slightly lighter and less ripe group (colour group 3).

In colour group 2, Cultar-treated fruit had more external damage after storage than those in colour group 3. Damage in group 2 exceeded acceptable export standards.

The results were clear: the post-harvest quality of the fruit from all regions is improved when they are harvested at a less mature stage in colour group 3 (colour chart index 5 – 6), when the fruit is still light in colour and the TSS is above the minimum export standard of 14%.

As far as NIR technology as a sorting tool is concerned, the study found that it could be used to non-destructively measure TSS but not firmness. Further studies should refine the potential of NIRs to grade 'Triumph' persimmons into distinctive TSS and fruit colour ranges.

WHEN THEY BLOW IN THE WIND

Persimmons are sensitive fruit that do not like strong winds. Windy conditions stress the fruit, causing them to produce ethylene which can lead to premature ripening. The fruit may, on the surface, seem to be in perfect condition but on the inside may already be softening – leading to shorter shelf life.

Growing as they do in the Western Cape, persimmons are occasionally subjected to the destructive force of the region's north-westerly wind.

"In view of these facts, we ran a second study alongside the maturity assessment trials to determine exactly how wind damages the persimmon industry," says Ferdie Ungerer.

The study employed four different ways of simulating the impact of wind. First, a spray machine blower was aimed at the fruit for five minutes at a time. Secondly, because wind strips leaves from trees, half the leaves of the tree sample were removed manually. The third method was to manually turn the fruit while they were still on the tree. Finally, trees were manually shaken for two minutes at a time.

The study found that wind did not affect the firmness of the fruit. However, defoliation and turning of stalks resulted in increased softening during storage. Colour development was increased during shelf life in the fruit of which the stalks were turned and where a wind blower was used. The TA was not affected by the wind.

"We will be sending the results to the technical guys at the storage facilities at Buffelsjag in Swellendam and Franschhoek," says Mr Ungerer. "They will pass on the information to the different farmers. It will then be up to the individual Sharon Fruit growers of the Western Cape to use the information and take the necessary steps to minimise losses."

The post-harvest quality of the fruit from all regions is improved when they are harvested at a less mature stage, when the fruit is still light in colour.

Integrated Packaging Solutions

Unpack the hnx

Boxes and cartons are more than containers in which fruit is transported. They are also the keepers of fruit quality. Their design is finally getting the attention it deserves.

About 90 million cartons are used annually in the export of citrus fruit and about 46 million in the pome sector.

THE BOXES IN WHICH FRUIT TRAVELS from the pack house to the shop have long been a neglected link in the export chain. Annual global fruit losses are staggering – as much as 40% – and poor packaging design has to shoulder part of the blame.

Without packaging fruit cannot be moved efficiently and in large quantities. The need for sound packaging to protect fruit against mechanical damage is well understood. The same cannot be said for the impact of packaging on other fruit quality attributes, as well as cooling efficiency and energy costs.

Packaging design for the fruit export industry is particularly challenging. Fruit lives and breathes and releases heat and moisture. If it is closed up in a container, microorganisms may grow and cause decay.

1 Prof. Linus Opara.
2 These computational fluid dynamics (CFD) visualisation of core fruit temperature show that fruit cools faster and more uniformly inside Supervent cartons than in standard A15C cartons.

Fruit needs to take in air and cool down to maintain its quality.

Forced-air cooling is generally used to cool fruit to required storage temperatures, while ventilated packaging helps to remove excess heat from inside and around the fruit to reduce respiration rates. It also facilitates rapid and uniform cooling.

A QUESTION OF DESIGN

Producers and exporters can choose from a variety of commercially available packaging options. But how does one know which is the best? There are many factors to consider: the size and number of the vent holes; how well the fruit will be protected and able to breathe, stacked in the middle of a number of pallets inside a shipping container; the impact of packaging on the pack house or cold store's energy bill; the ability of the box to withstand impact, vibration and compression; and the export market's packaging requirements.

These questions hint at the complexity of the packaging issue, and all the problems experienced in the cold supply chain related to inadequate packaging, confirm it. Until recently, however, the industry relied on past experience, anecdotal evidence and the need to trump the competition on aesthetics to guide its packaging design decisions. But that is about to change, thanks to the out-of-the-box approach of a team of researchers that is causing a 'revolution' in the packaging arena.

THE PROJECT

"Existing packaging options are not terrible, but if we accept the status quo, we miss out on opportunities to innovate, reduce cost and add value to our growers in an increasingly competitive global market," says Prof. Linus Opara, from the Post-harvest Research Laboratory at Stellenbosch University. "Innovation will help to ensure that the industry remains profitable, sustainable and internationally competitive."

Prof. Opara led the groundbreaking study that used engineering software to assess the performance of existing ventilated fruit packaging in terms of airflow, environmental control like temperature and relative humidity, fruit quality maintenance, the cost-effectiveness of materials and the refrigeration energy required for cooling. The latter is an important consideration. If the time needed to cool fruit down can be reduced, energy and cost will be saved. At the same time, the fruit's shelf life, health and even ripening process will be enhanced. All this can be achieved by optimising packaging ventilation.

"Our aim was to develop a validated mathematical model, applicable to all kinds of fruit, to predict the cooling performance of ventilated packaging," explains Prof. Opara. The resultant model will be used to design packaging that combines the best possible ventilation with structural strength. "We wanted a model that could visualise the airflow and heat transfer patterns inside and around fruit packaging," adds Prof. Opara. "This would enable us to develop practical guidelines for efficient and cost-effective packaging design. The ultimate intent is to design a new generation of innovative packaging that is light, strong, cost-effective, recyclable and intelligent."

The project team, based in Stellenbosch, consisted of Prof. Opara, Dr Mulugeta Delele and Dr Pankaj Pathare; Prof. Chris Meyer and Dr Corné Coetzee from the Faculty of Engineering; Dr Paul Cronjé from Citrus Research International (CRI)/Stellenbosch University; two post-doctorate and four MSc students.

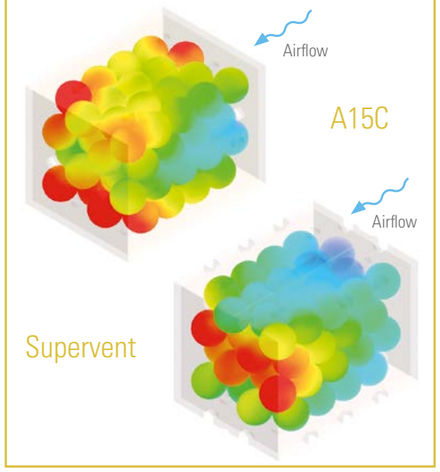
A NEW APPLICATION FOR CFD

Computational fluid dynamics (CFD) is a specialised area in computer and mathematical modelling

WHY PACKAGING NEEDS TO UP ITS GAME

- To limit wastage by reducing, reusing, recovering and recycling packaging.
- To limit the volume of packaging being used, and thereby reduce the industry's carbon footprint.
- To reduce cooling rates and, as a result, energy costs.
- To reduce post-harvest food losses and waste.
- To make the fruit industry more profitable and sustainable.

2 FRUIT CORE TEMPERATURE (SINGLE BOX)



PROJECT TITLE
Packaging of the Future: integrated model-based design and performance evaluation of packaging for the South African fresh fruit export industry

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DURATION
Two years

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LEAD INSTITUTION
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BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Integrated packaging solutions

HUMAN CAPITAL DEVELOPMENT
Two post-doctorate and four MSc students

PRESENTATIONS AND PAPERS
Five

PUBLICATIONS
Ten

Integrated packaging solutions

> "The ultimate intent is to design a new generation of innovative packaging that is light, strong, cost-effective, recyclable and intelligent."
> Prof. Linus Opara

used in industries such as aeronautics and nuclear fire and hazard management. Existing software was not designed with packaging analysis in mind, but the research team used ANSYS FLUENT software to simulate and predict airflow and heat transfer inside crates, fruit boxes, pallets, pack houses, cold stores and containers.

Funding from the PHI Programme, HORTGRO Science and SARChI Post-harvest Technology enabled the project team to purchase access to the CFD software and set up the experimental research infrastructure.

Prof. Opara thinks that this is probably the first time that CFD modelling is used in South Africa to better understand the fruit cold chain, specifically fruit packaging design and improvement. He explains that, when new packaging is designed, the usual process of manufacturing and repeated testing to meet the requirements of different fruit kinds is expensive and time-consuming. The novel approach of CFD modelling saves time and money. It simulates airflow patterns and heat and moisture transfer in and around ventilated packaging, which allows the team to study and predict the effect on fruit cooling rates. Package designs can be digitally assessed on the computer for as many times as necessary before involving manufacturing companies and embarking on three-dimensional testing.

"The strength of the project lies in the ability to test different scenarios beforehand by combining engineering and mathematical modelling with experimental studies," says Prof. Opara. "Without making a single prototype, we created hundreds of packaging vent design variations on the computer."

THE PROJECT FINDINGS

The research team focused their efforts on two main areas. The first was to assess the design of packaging vents to determine the ideal specifications for vent size, shape, number and positioning on the packaging. The second was the effects of storage conditions on the mechanical behaviour of ventilated corrugated packaging.

The team tested different packaging configurations, individual and stacked, during forced-air cooling. Some of the trials were conducted at the Stellenbosch University Post-harvest Research Laboratory and cold store facilities. They collaborated with industry role-players such as pack house operators, packaging companies and cold chain specialists. Outer and inner packaging were also tested for deciduous and citrus fruit. These included the specialised inner packaging for table grapes, such as SO_2 absorber sheets, carry bags and perforated poly-liners. In the long term, all the fruit sectors will be included in the trials.

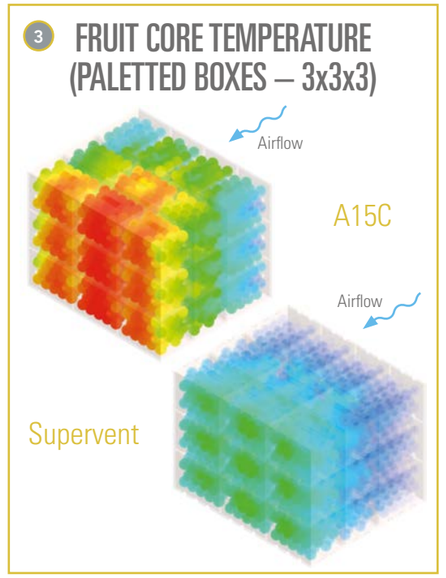
"We found that the percentage of vent area was the design parameter that had the biggest impact on airflow and produce cooling characteristics," says Prof. Opara. "It emerged that vents should take up about 7% of the box area for optimal and uniform airflow and cooling rate. Interestingly, we found that a 7% vent area also ensures the mechanical integrity of the packaging."

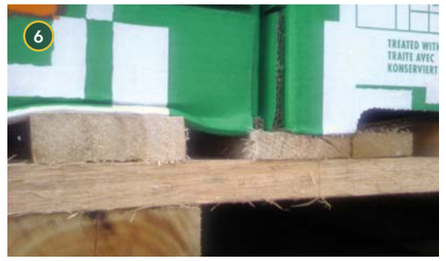
POSITIVE RESULTS

The research team successfully developed and validated mathematical models to predict the cooling performance of various fruit packaging solutions. This was used to formulate optimum package design and stacking parameters. They have put together a final model and developed practical guidelines to optimise packaging design for the South African fruit industry in future.

The benefits of this project are numerous and far-reaching. The researchers and post-graduate students who participated acquired valuable new skills in predictive packaging design and performance testing. This broadens their employment options and gives South Africa a competitive edge in packaging design internationally.

Furthermore, packaging solutions that reduce the incidence of fruit losses and financial claims will promote the reputation of the South African fresh fruit industry, leading to increased global competitiveness.





1 Some members of the packaging research team. Front (from left) Willem Gruyters, Dr Pankaj Pathare, Elrika Harmzeen and Karen Munhuweyi. Back (from left) Tobi Fadiji, Banji Oluwole, Tarl Berry, Dr Femi Caleb and Prof. Linus Opara.
2 The vent holes of boxes stacked onto a pallet need to align in order to allow optimal airflow to cool down the fruit. In this instance, the Sun Valley box design is ineffective.
3 This visualisation of heat transfer shows that fruit packed in Supervent cartons cools faster and more uniformly than those in standard A15C cartons.
4-5 What happens inside a single box of fruit is entirely different to what happens to boxes stacked on pallets inside a container being shipped overseas. The transfer of heat, airflow and moisture inside each box and the container as a whole, greatly influences final fruit quality.
6 Inadequate carton design, stacking and palletisation can result in mechanical damage of the carton and fruit, resulting in financial losses.

Carbon Footprint/Energy Efficiency in the Supply Chain

Energy well spent

Although it is impossible to arrive at a single figure, one can safely say that energy is a major input cost for the fruit export industry. It is also the cornerstone of the cold chain. The combination of keeping costs down and production up is reason enough to invest energy into energy efficiency.

The best performing pack houses use around 15kWh of electricity per ton of fruit packed, while others use three times as much.

IN 2008, South Africans were shocked into a new appreciation of electricity. For the first time that we remember, load shedding was a part of our lives. As the national electricity utility struggled to keep the lights on, both households and industry had a taste of life without power.

Although load shedding did not cause significant fruit losses, the export industry wisely decided to heed the warning. Further motivated by substantial electricity tariff increases and global pressure to reduce the industry's carbon footprint, an energy benchmarking project was launched under PHI-1 in 2008.

The aim was to develop and implement a benchmarking system for energy consumption on farms and at pack houses and cold stores to improve electricity and fuel efficiency. Koos Bouwer, industrial engineer and independent engineering consultant, was appointed to oversee and coordinate the project.

"The benchmarking results showed that it was virtually impossible to make generalisations about energy use in the industry," says Mr Bouwer. Not only did the different facilities' energy usage vary widely, they also paid vastly different tariffs – from less than R0,40 per kilowatt hour (kWh) to more than R1,40 per kWh. The best performing pack houses used around 15kWh of electricity per ton of fruit packed, while others used three times as much.

It was also clear that the different methods of cold storage had different energy implications. Storage of apples in a controlled atmosphere was extremely efficient at less than 1kWh per ton of fruit per day, whereas fruit packed in cartons on pallets used almost 8kWh of electricity per ton per day. "The important conclusion drawn from these varying results was that there were many opportunities for energy efficiency improvements," says Mr Bouwer. "If one pack house could be more efficient, there was no reason why others couldn't."

1

FROM "WHERE ARE WE?" TO "WHAT CAN BE DONE?"

In 2012, the United Nations Industrial Development Organisation (UNIDO) approached the South African government to take part in its Industrial Energy Efficiency (IEE) improvement project. Funded by the Swiss Secretariat for Economic Affairs and the UK Department for International Development, the local IEE project is hosted by the South African National Cleaner Production Centre (NCPC-SA) at the CSIR.

The IEE project focuses on five industry sectors, including agro-processing. Under the project's auspices, the NCPC-SA agreed with PHI-2 to conduct fully subsidised energy audits at interested pack houses and cold stores in the fresh fruit industry. The coordination task was again entrusted to Koos Bouwer.

"The process we followed was more an assessment than an audit," says Mr Bouwer. "Instead of looking at how facilities adhered to standards and specifications, the consultants assessed energy usage and trends." The difference between audit and assessment is also clear from the stated purposes of the project:

- Assist to quantify energy consumption at a facility and identify the significant energy users.
- Identify opportunities for the reduction and more efficient use of energy in the plant as part of an energy management plan.

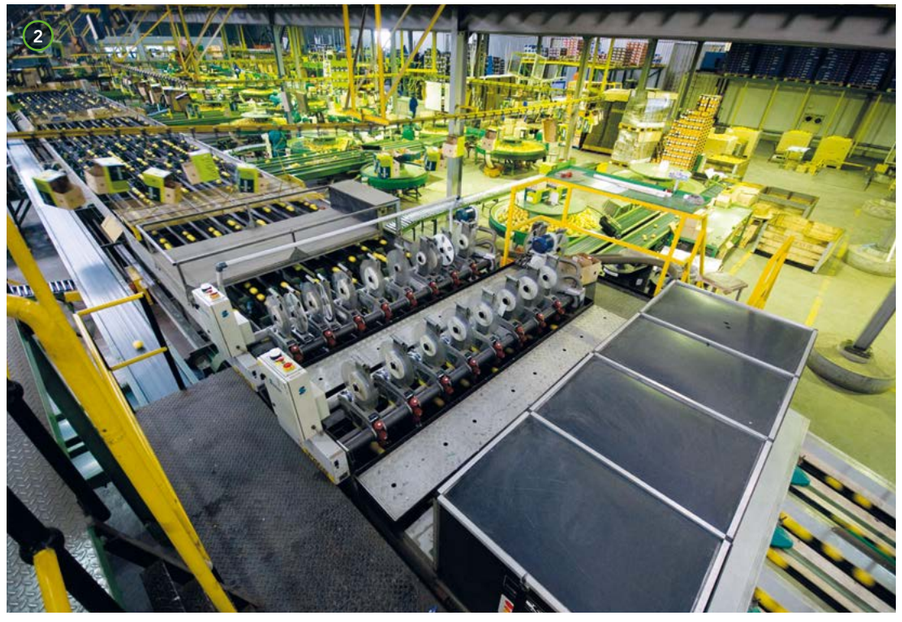
The energy efficiency audits initiative was rolled out in January 2012, when Mr Bouwer embarked on a campaign to raise awareness in the industry. He arranged several regional workshops where NCPC-SA representatives explained the nature and process of the project and recruited participants. Companies that wanted to participate signed a memorandum of agreement with the NCPC-SA. A total of 29 pack houses and cold stores agreed to take part.

The NCPC-SA assigned trained energy consultants to spend three to four days at each of the participating facilities. The audit was fully subsidised by the NCPC-SA. All the participants had to contribute, was their cooperation.

Once the audits were completed, the energy consultants discussed their detailed reports with the owners of each individual pack house and cold store. The reports highlighted, among others, savings options, results on feasibility, quantification of behavioural changes and the expected payback periods for energy saving investments.

THE FINDINGS

The 29 participating facilities had a combined energy usage of 101,1 megawatt hours (MWh) of electricity at a cost of R77 million for the year 2011. The energy audits revealed that they could save a combined 27MWh per year, putting R20,7 million back into their collective pocket. This 26,8% saving would require an investment of R26 million that will, on average, pay for itself in only 1,26 years. The potential electricity saving equals a reduction in CO_2 emissions of 27 000 tons per year



2

1 Koos Bouwer.
2 The best performing pack houses use around 15kWh of electricity per ton of fruit packed, while others use three times as much. The only way to improve facilities' energy efficiency is to use individual energy audits or assessments.

The energy audits were not a PHI research project. Instead the Programme helped pack houses and cold stores to access free energy audits that were offered by the Council for Scientific and Industrial Research's National Cleaner Production Centre (NCPC). Koos Bouwer worked with the NCPC to execute the initiative on behalf of PHI.

$

The energy audits revealed that the 29 participating facilities could save a combined 27MWh per year, putting R20,7 million back into their collective pocket. The potential electricity saving equals a reduction in CO_2 emissions of 27 000 tons per year.

Some of the areas in which considerable efficiencies can be gained are energy efficient lighting, variable speed drives and energy management systems. The single biggest opportunity, however, is to improve the efficiency of cooling equipment.

THE WAY FORWARD

Mr Bouwer points out that it is important to understand that the facilities are all unique and that the same change will have different impacts at different facilities. "It is literally impossible to generalise because one size does not fit all. The only way to improve facilities' energy efficiency is to use individual energy audits or assessments as the starting point."

A number of the facilities that took part in the audits are doing just that. Using their site-specific recommendations, they have started to implement the suggested energy efficiency measures and are reaping the benefits.

"The project seems to have acted as a catalyst," says Mr Bouwer. "It made the saving opportunities visible and facility owners are acting on it."

THE IEE IN ACTION

The objectives of the Industrial Energy Efficiency (IEE) improvement project are to:

- Contribute to the sustainable transformation of industrial energy usage practices in South Africa.
- Reduce carbon dioxide emissions.
- Demonstrate how energy efficient practices can increase profitability.

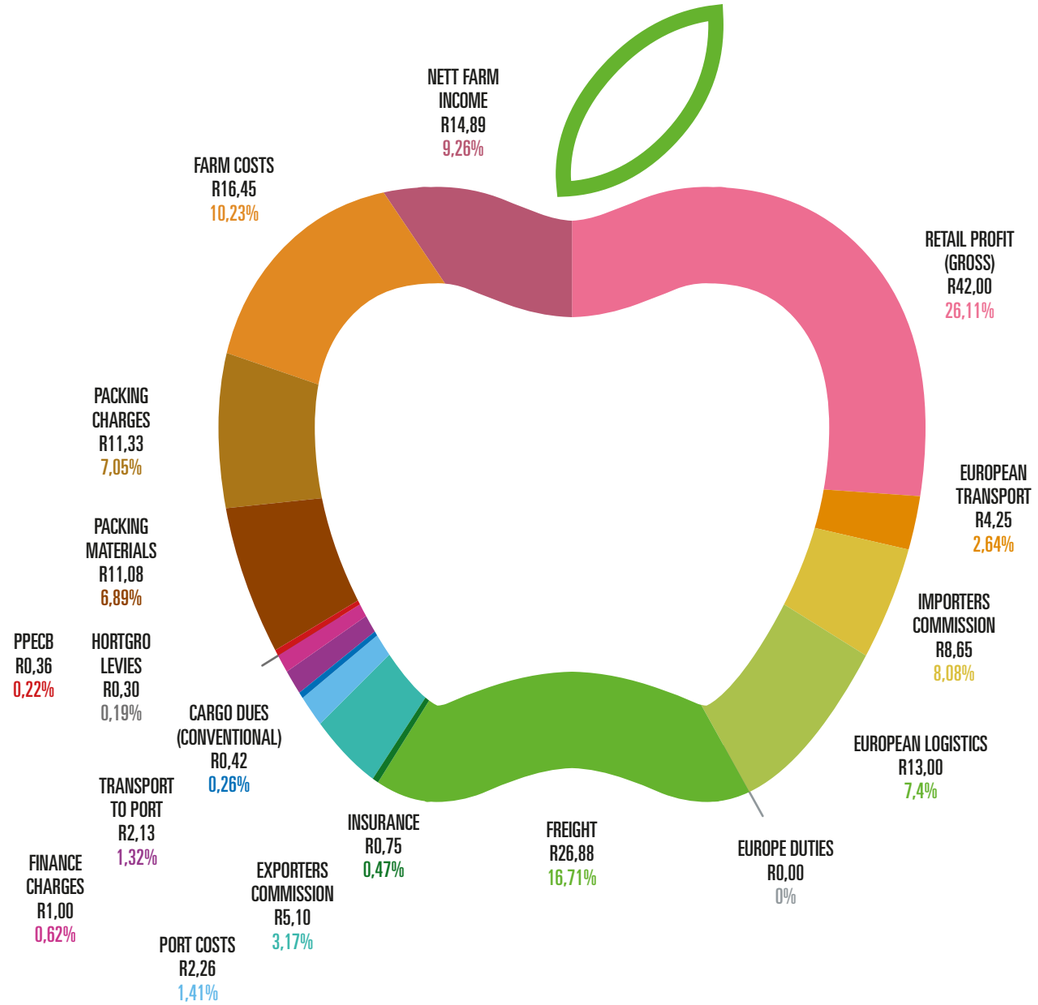
1 Different methods of cold storage have different energy implications. Storage of apples in a controlled atmosphere is extremely efficient at less than 1kWh per ton of fruit per day, whereas fruit packed in cartons on pallets use almost 8kWh of electricity per ton per day.

Carbon Footprint/Energy Efficiency in the Supply Chain

ANALYSIS OF COST CHAIN FOR APPLES

Selling price of R175,00 for 12,5kg

Source: Prof. Malcolm Dodd



Carbon Footprint/Energy Efficiency in the Supply Chain

Calculated containering

When a container of fruit is sealed in South Africa, there is no way of knowing what you will find when it is opened in Europe. This is set to change, thanks to the combined predictive powers of mathematical and computer modelling.

THE BEAUTY OF intermodal freight transport is that containers are closed at the start of their journey and only opened when they reach their destination. As far as fruit export is concerned, this is also the system's downside. There is no way of monitoring that the precious cargo is cold enough for quality to be preserved.

Keeping fruit from spoiling depends on maintaining the integrity of the cold chain, which is an energy-intensive and expensive undertaking.

Several initiatives are currently underway to reduce the energy used in the cold chain. Most of these depend on site visits and manual testing to determine energy usage and waste in cold chain components such as containers. This approach is expensive, tedious, time-consuming and, perhaps most importantly, not repeatable and scalable.

It is fortuitous, therefore, that Prof. Linus Opara, Research Professor and South African Chair in Post-harvest Technology at Stellenbosch University, has applied his mind to a solution. The result is a project to develop an experimentally validated mathematical model that can do the groundwork involved in improving energy efficiency in the fruit cold chain.

"The improper design and operation of cold chain systems cause a significant waste of energy," says Prof. Opara. "Not only does this cause unnecessary economic losses and an increased burden on electricity supply systems, but it is entirely avoidable."

With this in mind, Prof. Opara's team set out to develop a validated mathematical model of a cold chain handling system for fruit. The model will be used to evaluate the effect on energy consumption of different design and operational parameters of containers. At the end of the project the model will be applied as an industry training tool, called an energy health check, to demonstrate and recommend possible energy saving mechanisms in the cold chain.

1 Samuel Getahun, Prof. Linus Opara and Tarl Barry.
2 Samuel Getahun uses the CFD model to establish the airflow and heat transfer in a typical South African fresh fruit export container.

THE CFD-MODEL PROJECT OBJECTIVES

1 Develop a CFD model of airflow and heat transfer in a typical South African fruit export container.
2 Conduct experiments to validate the model.
3 Apply the validated CFD model to analyse the effects of different container design and operational parameters on the system's energy efficiency and recommend energy saving measures.

Although similar modelling has been done before, none has ever been applied to improve the energy efficiency of the cold chain. The innovation in this project lies in its ability to predict heat transfer inside a refrigerated container, and to quantify the contributions of the different components of the refrigeration system to the total energy use.

WHAT HAPPENS BEHIND CLOSED DOORS?

"Our starting point was to understand how air flows inside a shipping container," says Prof. Opara. "Air is used to cool the fruit but if it does not get to where the heat is, cooling does not take place."

The first phase of the project therefore entailed modelling the airflow in an empty container by using computational fluid dynamics (CFD), a powerful software tool. The model showed that even in an empty container, the air does not flow evenly. A large area at the door, which is furthest away from the refrigeration system, is cut off from the flow. Similarly, airflow is minimal in the middle of the container and is prone to turbulence due to the mixing of hot and cold air. The model suggests that, depending on where the pallet is placed in the container, the fruit will cool at different rates.

The next step is to physically test the model. This will entail the placement of temperature, air velocity and humidity sensors inside the container and mapping its interior to validate the computer model.

"Once we have completed the validation, and we have made the necessary adjustments to our model, we will place a pallet of fruit inside the container near the cooling system," elaborates Prof. Opara. Temperature, humidity and airflow data will be logged before the refrigeration system is switched on and recorded during the cooling process. The process will be repeated for pallets placed in the middle and at the door of the container. Throughout this process the readings will be tested against the CFD model.

The final step is to fill the container with pallets containing mostly plastic balls filled with a water solution to mimic the biophysical properties of fruit. Real fruit with probes inserted will be placed between the balls in order to ensure reliable data collection

PROJECT TITLE
Model-based quantification of energy utilisation and identification of strategies to improve savings and reduce wastage in the fruit cold chain

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DURATION
20 months

PHI-2 CONTRIBUTION
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LEAD INSTITUTION
Stellenbosch University (Faculty of AgriSciences)

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Carbon footprint / Energy efficiency in the supply chain

HUMAN CAPITAL DEVELOPMENT
One post-doctorate and one PhD student

PRESENTATIONS AND PAPERS DELIVERED
Two

PUBLICATIONS
Two

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If the containers of the Danish company, Maersk, were lined up, they would stretch more than halfway round the planet. If stacked, they would be 2 414km high — equal to 7 530 Eiffel Towers.

Source: www.telegraph.co.uk

without wasting fruit unnecessarily. Again, the data logged will be compared to the model predictions.

THE PRACTICAL APPLICATION

"Once we understand airflow in the container, we can model the cooling process by measuring heat transfer," says Prof. Opara. "This will tell us how long it takes to cool fruit from the pick temperature of about 25°C to -0,5°C during storage, which is the optimum cold chain temperature for many types of fruit."

Armed with all this information, the model can work its predictive magic. "We will be able to calculate how much energy is used to cool down both the fruit inside the box and the air inside the container. This will be used to calculate the efficiency of the refrigeration system."

Prof. Opara intends the model to be a tool for industry to test different scenarios. By simply running the model, the impact of different carton designs on cooling time can be determined. The same applies to different ways of stacking the boxes and aligning their vent holes.

Containers have a standardised design, but boxes and pallets come in different shapes and sizes. Therefore, in order to define the ideal operation of cooling systems, it is necessary to start with the packaging, says Prof. Opara. "The cost of cooling relates directly to the refrigeration unit, the type of packaging material and how the boxes and pallets are stacked. The model we are working towards will be able to tell a producer exactly how much it costs to have fruit in a refrigerated container."

It is not difficult to see why different cold chain participants are so excited about this project. Fruit producers, packaging and transport companies are eagerly awaiting the results and researchers in Europe and the United States have expressed interest in a knowledge exchange programme.

The power of the project is in the crystal ball. "This innovative tool allows us to ask the 'What if' questions that are expensive to answer by doing physical experiments," says Prof. Opara. "In future, with this model, we will be able to assess box designs and advise people on how best to load a container. And I see no reason why we can't change container designs too …"

THE BEAUTY OF THE MODEL

The mathematically validated CFD model can:

- Provide a quick and in-depth understanding of the factors that contribute to energy usage and waste.
- With minimum data on the characteristics of a container, accurately predict different scenarios without the need for expensive data collection and extended monitoring.

1 This container on campus is valuable for executing airflow and cooling patterns.
2 The CFD model can tell what happens behind the closed doors of a fresh fruit export container.
3 A stack of container refrigeration systems at Cape Town harbour.

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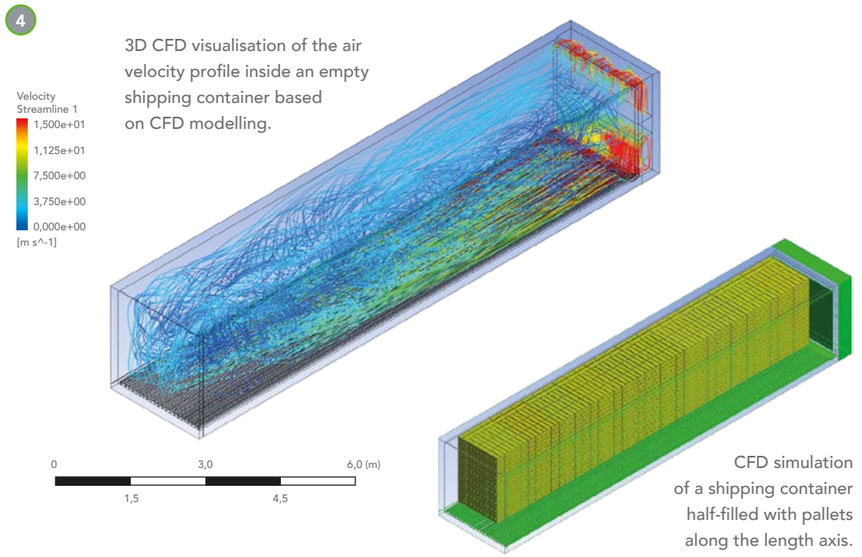
The world's biggest container ships can carry 15 000 boxes. One ship can hold 746 million bananas — one for every person in Europe.

Source: www.telegraph.co.uk



3D CFD visualisation of the air velocity profile inside an empty shipping container based on CFD modelling.

CFD simulation of a shipping container half-filled with pallets along the length axis.

3D CFD visualisation of airflow patterns inside an empty shipping container showing an optical slice taken at 1,2m (above) and 0,6m (below) from the edge of the container.

Airflow path lines are coloured by velocity magnitude (m/s).

4 Top: CFD simulation results showed that airflow varied considerably inside the container and was lower near the container door compared to the inlet point near the refrigeration unit (in red). This implies that fruit inside pallets near the door will take much longer to reach the target temperature required to maintain quality.
Middle: CFD modelling can be used to generate computer geometries of the container and pallets with different stacking and filling scenarios. Here is an example of pallets stacked inside a container half full along the length axis.
Bottom: Results of CFD modelling and analysis showed that airflow was more uniform near the container wall (below) and became more turbulent towards the centre (above). Better air mixing (below) provides more contact between the cold air and warm materials (carton, fruit) that need to be cooled.

Carbon Footprint/Energy Efficiency in the Supply Chain

Bananas light the way

Perfect ripening and storage are all about channelling the right amount of energy to the right equipment at the right time. Bananas are helping to shed light on these energy issues.

THE BANANA RIPENING CENTRE at the Tshwane Market is an energy-intensive operation. Fifty-five cold rooms, each around 200m³ in size and equipped with four fans, operate around the clock, every day of the year, to either store or ripen tons of bananas.

The fruit arrives completely green from the Mpumalanga and Limpopo provinces' subtropical fruit growing areas. Depending on their export schedule, the unripe bananas are either cooled down and stored for a few days at around 12°C, or ripening is induced straight away at between 15°C and 16°C. Under normal circumstances ripening takes nine days but when demand threatens to outstrip supply, the process is compressed into six days.

Temperature control is both a science and an art, because bananas can 'hold a grudge'. Any mistreatment while the fruit is still green shows up in black spots or uneven ripening later on.

Given its combined energy use for cooling, storage and ripening and the demands that this places on temperature control, the Banana Ripening Centre was the ideal testing ground for a study into the options available to reduce the energy consumption in the fruit export cold chain by introducing energy efficient technologies.

Experience in other markets has shown that the energy use of cold rooms can be cut by 20-30% by adopting measures such as reducing the heat load, introducing variable speed drives (VSDs), optimising airflow patterns, improving operating and maintenance practices and implementing automatic controls.

An appreciation of the value that more energy efficient practices can add to the fresh fruit industry, prompted the Post-Harvest Innovation Programme to collaborate with the Tshwane University of Technology (TUT) in Pretoria in a project to identify energy conservation measures that can be applied in cooling facilities in the fruit cold chain.

The study was done by Master's degree student, Jean-Claude Mulobe, under the supervision of Prof. Zhongjie Huan from the TUT Department of Mechanical Engineering.

1 Cool bananas! By reducing the speed of an electrical motor by just 10%, its energy use can be cut by 20%.
2 Each cold room has four of these electrical fans that circulate cold air. They enable the required cooling and ripening processes, but consume a considerable amount of energy.

PROJECT DESIGN AND RESULTS

The study involved the experimental and/or theoretical investigation of energy saving technologies that can be implemented in cooling facilities that have both cooling (temperature dropping) and cold storage (temperature maintaining) functions.

The project started with an energy audit of the Banana Ripening Centre at the Tshwane Market. The facility consumes just more than 668MWh of electricity in a year. The biggest consumers, at almost 60% of the total, are the refrigeration facilities, namely the cooling rooms, refrigeration compressors and cooling plant.

The energy audit mapped the centre's overall energy consumption, isolated the energy consumption of the refrigeration system and recommended energy conservation measures.

Based on the results of the audit, Mr Mulobe built and verified a numerical simulation computer code to simulate the refrigeration system. This allowed him to test, in theory, the impact it would have to run the motors of the evaporative coil fans in the cool rooms with VSDs. Two VSD modes were tested, namely constant and variable.

Mr Mulobe's computer modelling also investigated how airflow patterns and stacking methods influence energy consumption. Staff members at the Banana Ripening Centre already know that the two-way pallets, which are open on two sides to allow easy forklift access, is better for airflow than the four-way pallets. Two-way

WHY EFFICIENCY MATTERS

Cooling facilities that are more energy efficient is good news for the industry because of:

- Reduced energy costs.
- Reduced operation and maintenance costs.
- Improved system reliability.
- Improved safety.
- Increased productivity.
- Better matching of refrigeration load and equipment capacity.
- A better working environment.

PROJECT TITLE
Energy efficient technologies and energy saving potential for cooling facilities in the fruit cold chain

PRINCIPAL INVESTIGATOR
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DURATION
One year

PHI-2 CONTRIBUTION
R260 000

LEAD INSTITUTION
Tshwane University of Technology (Department of Mechanical Engineering)

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Energy sufficiency in the supply chain

HUMAN CAPITAL DEVELOPMENT
One post-doctorate, two MTech and two BTech students

PRESENTATIONS AND PAPERS DELIVERED
Six

PUBLICATIONS
Two

VSDs combined with airflow optimisation have the potential to reduce energy usage in the cold rooms at the Banana Ripening Centre by up to 18%.

pallets' two open sides can be closed with metal strips to 'trap' the circulating air. This allows the air to circulate more evenly and efficiently between the boxes stacked on the pallet. Four-way pallets, that are open to the floor on all four sides, cannot be closed off as easily, making it more difficult to achieve sufficient airflow between the boxes. With the computer modelling, airflow and stacking practices are elevated from anecdotal evidence and trial-and-error to verified science.

The VSD and airflow studies were also put to the test in real life. In a small experimental cold room on the TUT campus, pallets of bananas were subjected to different experiments with VSDs and ways to optimise airflow to determine the impacts on both energy consumption and fruit quality. The variable VSD was proposed and verified as an effective way to save energy and maintain fruit quality. The experiments concluded that VSDs, combined with airflow optimisation, have the potential to reduce energy usage in the cold rooms at the Banana Ripening Centre by up to 18%.

The other theoretical part of the study was the mathematical modelling of how a cold room's colouring and shading can contribute to energy savings by reducing the transmission heat load. The findings indicate that colouring and shading have the potential to reduce the heat load on a cold room by as much as 36%.This technology has the potential to be applied and patented.

WIDER APPLICATION

Although this energy efficiency project used the Banana Ripening Centre as its laboratory, its results and insights are directly relevant to the broader fruit cold chain, since its scope covered technologies that are applicable to all types of fruit that need a low-temperature environment.

There are also wider application possibilities. For example, the software Mr Mulobe developed can be used to model food freezing, cooling and heating for purposes of processing and equipment design, optimisation and understanding.

Beyond technical returns, the cost savings that result from improved energy efficiency directly benefits people by making money available for business expansion. The result is more jobs, often to the advantage of women, since they seem to be more involved in trading and marketing of fruit than men.

Better matching of refrigeration load and equipment capacity will greatly reduce post-harvest losses. This should encourage specifically emerging farmers to increase production leading to positive cash flow and higher net incomes.

The employment benefits extend beyond the fruit industry. Increasing demand for energy efficiency solutions will have positive effects on employment, directly by creating new business opportunities and indirectly through the economic multiplier effects of spending the money saved on energy costs in other ways.

WHAT IS A VSD?

A variable speed drive (VSD) is a piece of equipment that regulates the speed and rotational force, or torque output, of an electric motor.

There are millions of motors in use in industry and offices around the world. They operate pumps, milking machines and ski lifts, paper machines and power-plant fans, sawmill conveyors and hospital ventilation systems, to name just a few examples.

In fact, more than 65% of industrial electrical energy is consumed by motors.

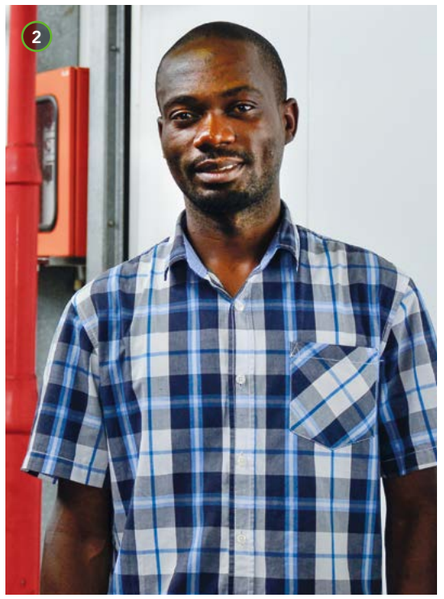
In many cases, motors are controlled by means of a valve that regulates the flow of fuel, or a vane that controls the airflow, while the speed of the motor itself remains unchanged. These and other methods, such as using two-speed motors or controlling motors by switching them on or off, are inefficient from an energy point of view.

One of the main reasons why drives save energy is because they can change the speed of an electrical motor by controlling the power that is fed into the machine. Reducing the speed of an electrical motor by just 10% can reduce its energy usage by 20%.

Source: www.abb.com

Carbon Footprint/Energy Efficiency in the Supply Chain

Beyond technical returns, the cost savings that result from improved energy efficiency directly benefits people by making money available for business expansion.



1 Prof. Zhongjie Huan and Jean-Claude Mulobe.
2 The results and insights that Jean-Claude Mulobe gained in this project are relevant to the broader fruit cold chain.
3 The energy consumption of the refrigeration facilities of the Banana Ripening Centre at the Tshwane Market has been decreased considerably by minor adjustments to the speed of the cooling fans.

Carbon Footprint/Energy Efficiency in the Supply Chain

The sunny side of saving

A new computer-based tool is helping cold store and pack house owners to look at their electricity bills through solar-tinted glasses.

Energy audits at 29 facilities have indicated that solar energy can, on average, shave 27% off a pack house or cold store's electricity bill.

THEY DON'T CALL IT 'SUNNY SOUTH AFRICA' for no reason. Most parts of the country enjoy an average of 2 500 hours of sunshine per year, giving us one of the best solar resources in the world. Yet, the uptake of renewable energy, including solar, has been slow.

For several decades, South Africa had the cheapest electricity in the world. This, coupled with a general ignorance about climate change and the need to conserve the environment, had us turning a blind eye to the infinite source of energy at our disposal.

In 2008, however, widespread rolling power outages gave South Africans the wake-up call they needed. It became glaringly obvious that the national energy supply was under pressure and that the days of cheap and abundant electricity were over.

The fresh fruit industry is not shielded from energy pressures. Electricity supplied by the national utility is becoming increasingly expensive and carries a heavy carbon emission burden. The industry faces a possible carbon tax at home and pressure abroad as consumers in export markets demand fruit that is as free of CO_2 emissions as possible.

Although agriculture will not be taxed directly, it is possible that Eskom may add a tax factor into its cost/kWh. This means that carbon will be an input cost.

CASE STUDY

Arbeidsvreugd Fruit Packers (Pty) Ltd, Villiersdorp.
System size: 450kWp (kilowatt peak)
Electricity generated: ± 743 000kWh per year
CO_2 avoided: ± 733 tons per year
Savings: ± R600 000 in the first year
Total savings over 25 years: ± R38 million
Payback period: ± six years

According to Government's latest carbon tax table, businesses can offset up to 10% of electricity-related carbon costs in their annual tax returns.

Understanding that the energy challenge needs to be addressed, the Post-Harvest Innovation Programme initiated a project to raise awareness in the fresh fruit industry about the potential of solar energy to bring down energy costs.

While the sun gives its energy for free, the infrastructure to harness it involves a significant investment. Knowing which solution to install requires specialised information – which usually comes at a considerable cost. Clemens Brandt from RED Engineering was therefore tasked to develop a tool that would empower producers to evaluate the viability of implementing solar energy at pack houses or cold stores and for household or other business uses.

A TOOL FOR ALL

Mr Brandt and his team's solution is a web-based tool that can be used to conduct a free, on-line analysis of the potential cost and savings of a solar power solution. "We've also untangled all the intricacies involved in integrating Eskom electricity with a solar system – from household to industrial scale," says Mr Brandt.

The process couldn't be simpler. Apart from electrical consumption data for a 12-month cycle, the model requires the user to punch in the location of the facility, the area available for solar panels, the angle of the roof and the direction it is facing, current electricity cost structures, maximum electricity demand, cost per unit and total cost.

In response, the model generates a report that provides the user with all the information necessary to make an informed decision about an investment in a solar photovoltaic (PV) system. It makes recommendations in terms of the size and technical

1 Clemens Brandt.

PROJECT TITLE
The development of a solar power viability model for the implementation of solar electricity generation at pack houses and cold stores

PRINCIPAL INVESTIGATOR
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DURATION
One year

PHI-2 CONTRIBUTION
R240 000

LEAD INSTITUTION
RED Engineering (Pty) Ltd

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Energy efficiency in the supply chain

Solar energy is safe, environmentally friendly and the most readily accessible energy source in South Africa.

Each kWh of Eskom electricity equates to approximately 1kg of CO_2 emissions.

The PV system has an assumed lifetime of 25 years.

The solar power decision-making model is available to all pack houses and cold stores, at no cost.

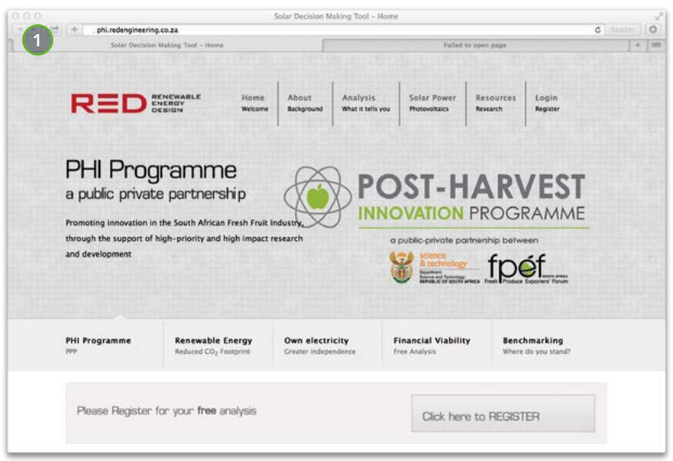
characteristics of the PV system most suitable to meet the energy needs of the facility, based on the data profile, and supplies costing calculations.

Finally, the model analyses and calculates the approximate investment cost based on current product prices, rates, the projected electricity expenditure, the seasonality of the client's industry and the seasonality of solar power levels. Armed with all this information, the producer can make a decision to invest or not and is equipped to negotiate with his PV system supplier of choice.

"The fruit industry's electricity profile is unique, given the seasonal nature of its energy demand," says Mr Brandt. "Add to that the fact that solar energy supply is also seasonal, and one can see why the PV decision is not a simple one and why a solar solution has to be integrated with the Eskom supply."

The tool that Mr Brandt and his team developed can be used by all South Africans to do an independent analysis of their electricity consumption data – at no cost. The results of the analyses are meant to serve as a basis for further discussion and analysis before the homeowner or business owner comes to a final decision regarding the switch to solar energy."Even though RED Engineering is the author and initiator of the analysis system, users are free to approach any player in the industry to help them make a final decision," says Mr Brandt. "Our aim is to help users achieve the optimum balance between solar power and Eskom-supplied electricity and to reduce energy cost and carbon emissions over the long term."

1



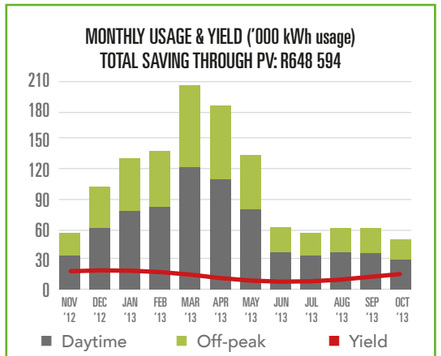
HOW DOES SOLAR ENERGY WORK?

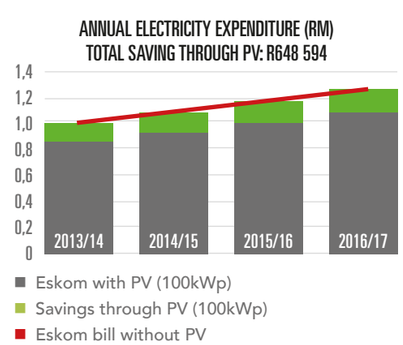
Solar panels collect solar energy, or sunlight, and convert the radiant heat into energy to produce electricity.

A solar power system consists of solar panels, inverters, optional batteries and a charge controller. Solar panels are connected assemblies of several photovoltaic cells. Each individual cell is coated with a positive and negative layer to create an electric field.

As photons from the sun, or sunlight energy particles, enter a cell, they allow the electrons in the cell to become free. The free electrons flow through a wire connected to the photovoltaic cell and becomes electricity.

Source: livinggreenmag.com





Carbon Footprint/Energy Efficiency in the Supply Chain

2

3

To investigate the viability of solar energy for your pack house or cold store, visit http://phi.redengineering.co.za

1 The PHI/RED Engineering website that hosts the solar energy decision-making tool.
2 Inverters convert DC current from the photovoltaic panels to AC current for grid use.
3 The 450kWp photovoltaic installation in Villiersdorp. The 1 876 panels produce more than 3 000kWh of electricity on a sunny summers day.

Pretty in pink

A simple solution brings a blush to the cheeks of pink grapefruit – and solves a chilling export dilemma.

> Higher levels of lycopene in the coloured part of the rind reduce the fruit's sensitivity to chilling injury.

REMEMBER how your mother used to say that too much of a good thing is bad? Nothing could be truer for grapefruit in the cold chain. In the fresh fruit export industry, cold sterilisation is a way of eliminating pests such as the false codling moth larvae. But when it gets too cold, typically below 4,5°C, the rind of grapefruit pits or scalds – a phenomenon known as chilling injury.

Many countries have their own protocols that govern the handling of fruit exported to them. These include cold chain requirements. Japan, for example, demands that citrus exports have to be kept at -0,6°C for 12 of the days it is in transit. The American and Chinese requirements are even more extreme, extending the period to 24 days.

For grapefruit, these requirements are clearly too much of a good thing.

1 Dr Paul Cronjé.

LYCOPENE TO THE RESCUE

In an attempt to resolve the chilling injury conundrum, researchers have found that yellow grapefruit cultivars are more susceptible to chilling injury than the pink ones. It turns out that the pink cultivars are naturally protected by a molecule called lycopene, the same molecule that gives 'Star Ruby' grapefruit its pink colour. Higher levels of lycopene in the coloured part of the rind reduce the fruit's sensitivity to chilling injury.

This significant finding about lycopene in grapefruit led to a Post-Harvest Innovation Programme project in which Citrus Research International (CRI) collaborated with Spanish citrus researchers at CISC-IATA in Valencia, to find ways to increase the production of lycopene in 'Star Ruby' grapefruit in order to reduce incidences of chilling injury.

To achieve this goal, three objectives were set:

- Find ways to influence pre-harvest fruit development to increase lycopene content in two diverse climates, namely Kakamas (desert) and Hoedspruit (subtropical). Grapefruit from Kakamas is exported to the USA, while Hoedspruit's produce goes to China and Japan.
- Develop post-harvest treatments to increase lycopene.
- Develop colour charts and sorting techniques that can be used in the pack house to decide which fruit should be sent to which markets, depending on whether or not there is enough lycopene present in the rind to withstand cold sterilisation temperatures.

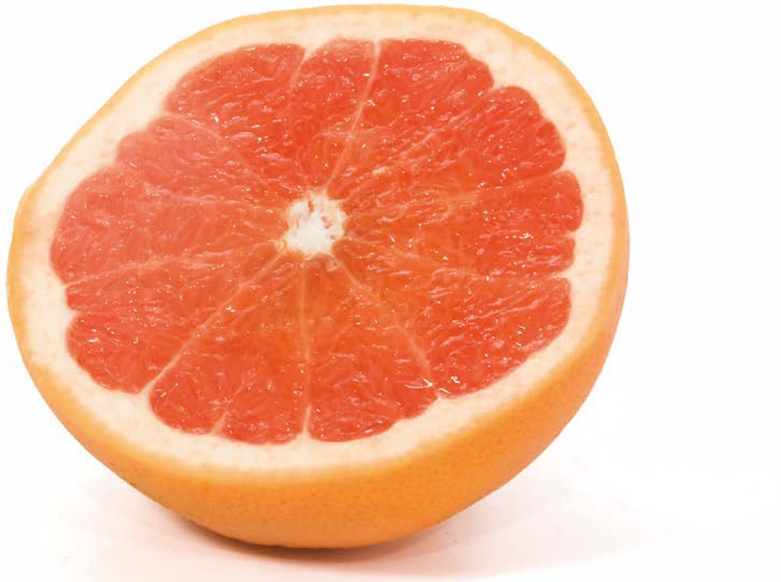
Dr Paul Cronjé, who is seconded to the Department of Horticultural Science at Stellenbosch University by CRI, led the South African part of the study. The Spanish researchers were Dr Lorenzo Zacarías, Dr Maria-Jesus Rodrigo and Dr Joanna Lado.

THE LOWDOWN ON LYCOPENE

Apart from making 'Star Ruby' grapefruit pink, lycopene also colours tomatoes red. It is not, however, responsible for the colour in strawberries.

The synthesis of lycopene in grapefruit occurs in semi-shade conditions and differs significantly from the synthesis in other fruit species such as tomatoes.

In addition to being a pigment, lycopene is also a carotenoid (the pigment in citrus fruit that colours the rind and pulp) and an extremely potent antioxidant. Its health benefits include reducing the risk of prostate cancer.



WHAT THE STUDY FOUND

Firstly, it was confirmed that the redder the grapefruit, the less susceptible it was to chilling injury. Lycopene was indeed the secret weapon.

The pre-harvest experiments were done in Kakamas, Hoedspruit and Valencia in Spain and involved covering the fruit with paper bags. "We found that this increased the lycopene content in the rind, but only when the fruit was shaded during stage 2

PROJECT TITLE
Increased lycopene content in the fruit flavedo to reduce chilling injury of grapefruit during cold sterilisation shipments

PRINCIPAL INVESTIGATOR
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DURATION
Two years

PHI-2 CONTRIBUTION
R310 184

LEAD INSTITUTION
Citrus Research International and Stellenbosch University (Department of Horticultural Science)

BENEFICIARY
The citrus industry

FOCUS AREA
Pre-harvest disposition to post-harvest disorders

PRESENTATIONS AND PAPERS DELIVERED
One

PUBLICATIONS
One

Pre-harvest disposition to post-harvest disorders

USA

Using the results of this study, producers are enjoying great success with exporting grapefruit with high lycopene content to the lucrative USA market, where prices are up to 30% higher than elsewhere in the world.

growth, which is from December to January in South Africa," says Dr Cronjé. The team furthermore found that direct sunlight seemed to burn away the lycopene pigment, leading to fruit rind that is susceptible to chilling injury.

An important finding was that lycopene content can only be increased in the orchard. Current techniques to increase the pink colour, such as pre-harvest Ethephon and post-harvest ethylene gas treatments, only remove the green in the rind. "The answer to our research question was therefore simple," says Dr Cronjé. "The only way to increase the lycopene content is to give the fruit shade while it develops."

Based on these findings, the research team's pre-harvest recommendations are to manage the orchard well with irrigation and initial fertilisation to ensure good canopy development that allows the fruit to grow in the shade. Due to the extreme temperatures in the Kakamas area, shade netting could be used to ensure the development of evenly pink grapefruit.

Post-harvest recommendations include selective harvesting. To this end, pickers in the orchards and packers in the pack houses should be trained to use the colour charts to select fruit that is pink enough to withstand cold sterilisation temperatures.

The results of this study have handed producers two extremely useful and practical tools to increase export production. The first is low-cost technology to increase lycopene content in 'Star Ruby' grapefruit. The second is colour charts that enable producers to select their target market based on the colour of their fruit. Depending on how pink the grapefruit is, producers can decide to ship it under normal (4-10°C) or sterilisation (-0,6°C) temperatures.

COLOUR TALKS

One of the outcomes of the 'Star Ruby' grapefruit study was colour charts that are now being used in pack houses to help make export decisions.

It is suggested that fruit that is completely pink (number 1 on the chart) or more than 80% pink (number 2) could be exported to the USA.

Fruit with a 60% to 80% pink cover (numbers 3 and 4 on the chart) can be exported to Japan, provided it is waxed or treated with TBZ. Because Japan requires a shorter cold sterilisation period, there is a lower risk of chilling injuries.

However, fruit that is less than 60% pink (numbers 5 to 8 on the chart), should not be shipped under cold sterilisation treatment temperatures and should preferably be exported to non-steri markets.

WHAT ARE STERI MARKETS?

South Africa is the world's largest exporter of fruit via shipping – more than 60 countries receive our produce by sea. An increasing and significant portion of South African citrus is exported to so-called steri markets, such as Japan, China and the USA.

Steri markets are countries that prescribe the use of cold treatment to ensure that they don't import pests along with the fruit that arrives in their ports. Although South Africa also uses cold treatment to eliminate pests and diseases, the local treatment conditions are not always the same as those prescribed by other countries.

Treatment conditions include 12 days at ±0,6°C for fruit fly disinfestation (*Ceratitis capitata* and *Ceratitis rosa*) and 22 days at below -0,3°C or 0°C for false codling moth (*Thaumatotibia leucotreta*).

1 'Star Ruby' grapefruit, depleted of lycopene, scars easily when chilled.
2 'Star Ruby' grapefruit that grows in full shade develops high levels of lycopene. Exposure of the fruit surface to direct sun 'bleaches' the lycopene from the rind resulting in higher susceptibility to chilling injury.

Technology and Knowledge Transfer

4+1 Four manuals, one mission

Perfect fruit perfectly delivered is the holy grail of the fruit export industry. A recently completed project delivered four how-to guides for those who pursue this quest in the citrus cold chain.

> "By improving protocols and practices along the cold chain, the citrus industry can prevent losses running into millions of Rands due to waste."
> Hannes Bester

STANDARD POLICIES AND PRACTICES are a cornerstone of the citrus export industry. Every single person who handles the fruit – from picking to packing to point of sale – has to know what he or she is doing and, more importantly, the correct way of doing it.

Hannes Bester is the area extension manager for the southern part of the country at Citrus Research International (CRI), based in Port Elizabeth in the Eastern Cape. Between mid-2011 and mid-2013, he led a project to improve cold chain technology transfer in the citrus industry. The result was four manuals that show employees exactly how to handle the fruit in their link of the cold chain. These manuals were compiled and updated by Keith Lesar, the extension officer responsible for post-harvest technology transfer in the CRI Extension Department.

Fruit lives and changes until the consumer finally bites into it. What starts out as a tiny nick or bump or blemish, can over time develop into a wound or a disease that will spoil the fruit. No activity in the cold chain is therefore too big or too small to be meticulously controlled. This is why the transfer of skills, knowledge and methods of manufacturing – collectively known as technology transfer – is so important.

Mr Bester describes technology transfer as a powerful tool. "It is a key element in keeping the South African citrus industry globally competitive. If applied properly, it can raise the quality of all the cold chain components to enhance the shelf life of the fruit."

Although the CRI Post-harvest Technical Forum (CRI-PTF) had manuals and procedures in place previously, the industry agreed that they had to be updated to reflect the latest developments. Funded by the Post-Harvest Innovation Programme, Mr Lesar set out to produce an illustrated post-harvest disease manual, standard operating procedures (SOPs) for pack houses and a decay control checklist, and to update the CRI Production Guidelines. The first three documents are also being included in the CRI Production Guidelines. In this way, the widest possible technology transfer will be accomplished across the supply chain

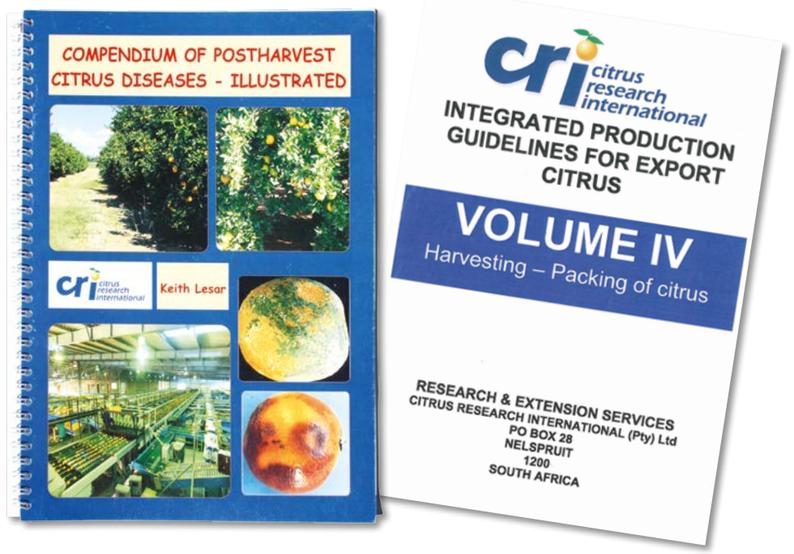
"Each of the four elements exists as a separate entity," explains Mr Bester. "But they serve a collective set of objectives." These are to ensure that citrus is handled within the best time and temperature protocols; that the best practices for fruit handling, packing, palletising and transport are applied; that cooling and humidity are efficiently controlled; that resistance to certain post-harvest fungicides is managed; that fruit decay is controlled and that good quality packaging materials are used.

The overarching aim is to consistently deliver citrus fruit of superior quality to our markets, at home and abroad. In so doing, the global competitiveness of the South African citrus industry should be improved.

THE FOUR MANUALS

1 Compendium of Post-harvest Citrus Diseases
This illustrated guide assists citrus growers, pack house managers and fruit inspectors at both local ports of departure and international ports of arrival, to correctly identify post-harvest decay and diseases.

Accurate feedback is the important issue here,



KEEPERS OF CITRUS QUALITY

South Africa is one of the largest citrus exporters in the world. The vast citrus industry is tightly structured to ensure proper management. Citrus Research International (CRI) coordinates research and technology with the support of the Citrus Growers' Association (CGA). There are four departments within CRI: Research, Extension, Cultivar Development and the Citrus Improvement Scheme, with the CRI Post-harvest Technical Forum (CRI-PTF) falling under the Extension Department. The CRI-PTF is responsible for post-harvest technical coordination and technology transfer.

PROJECT TITLE
Citrus Cold Chain Forum facilitates technology transfer

PRINCIPAL INVESTIGATOR
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DURATION
Two years

PHI-2 CONTRIBUTION
R188 000

LEAD INSTITUTION
Citrus Cold Chain Forum

BENEFICIARY
The citrus industry

FOCUS AREA
Technology/knowledge transfer

PRESENTATIONS AND PAPERS DELIVERED
Eight

1 Hannes Bester.
2 Two of the four manuals that were produced to advance knowledge transfer in the citrus industry.

The South African citrus industry has to contend with between 12 and 14 different types of post-harvest fungal diseases. The majority of the economic losses, between 80% and 90%, are caused by only 23% of the infectious agents, or pathogens, that cause diseases once fruit is in the cold chain.

says Mr Bester. "Locally, export marketing agents often receive reports from fruit inspectors overseas, flagging citrus consignments for waste types such as sour rot, blue and green mould and brown rot. However, on closer inspection we discover that the diseases have been wrongly identified. This makes it very difficult to implement the appropriate and timeous corrective action."

The Compendium of Post-harvest Citrus Diseases was launched at the CRI pack house workshops during January and February 2013 and proved its worth during the year's citrus season. "Industry players tell us that the photos and descriptions helped employees to correctly identify infections at all the critical points along the cold chain, most importantly at the international ports of arrival before the fruit went into the markets for sale," says Mr Bester.

2 Decay Control Checklist for Citrus Pack Houses

Every step of the journey, from orchard to market, plays a role in the control of post-harvest citrus diseases. None of the role-players can undo the harm inflicted on the fruit at a previous step, and each has a duty to deliver a sound product to the next phase.

While pack houses can certainly contribute to quality problems by not having adequate checks and balances in place, they are too often blamed when poor quality products reach the market and financial losses are suffered.

Mr Lesar compiled the pack house checklist by distilling recommendations he gathered from workshops, study group meetings and pack house visits. It is an easy-to-use daily management tool to help manage the critical control points that prevent decay and improve shelf life.

Industry feedback is confirming the usefulness of the checklist. In addition to being a management tool, pack house managers are using it to manage and record the functioning of the pack house critical control points. They also use it to conduct in-house audits. The checklist can serve a similar auditing purpose for export agents.

SPREADING THE WORD

Successful knowledge transfer extends beyond the production of documents. Making the industry aware of the tools and training people on how to use them, were important aspects of Keith Lesar's responsibilities. During the two-year duration of the project, he:

- Consulted and paid visits to more than 200 citrus pack houses during the 2011, 2012 en 2013 packing seasons.
- Spoke at the CRI Citrus Symposium every second year, reaching 500+ delegates with the knowledge transfer message.
- Presented to more than 650 delegates at the annual CRI pack house workshops in Limpopo, Mpumalanga, KwaZulu-Natal, Swaziland, Eastern Cape and Western Cape.

Articles about the project and its outcomes were published in *SA Fruit Journal* and in the CRI's electronic newsletter *Cutting Edge*.


1


2

3 SOPs for Citrus Pack Houses

The SOPs for pack houses is a shortened version of Volume IV of the Citrus Production Guidelines. The simple format in which it describes best handling procedures and protocols helps to manage the movement of the fruit from the orchard, through the pack house and into the container trucks. It covers, among others, receiving the harvested fruit, drenching the fruit prior to de-greening, pre-sorting, washing and drying, waxing treatment, sizing, packing and palletisation for shipping.

The SOPs are being welcomed by the pack houses as a tool to manage and record their critical control practices and procedures more efficiently. The fact that the pack house manager can repeatedly apply unchanged processes and procedures contributes to a disease-free, high-quality product.

4 Citrus Production Guidelines

The existing Citrus Production Guidelines Volume IV, called Harvesting and Packing of Citrus, has been updated.

Each component of this project targets specific areas in the supply chain and are designed to bring about positive changes. The new manuals, whether used individually or as part of the CRI Production Guidelines, should help role-players to adhere to food safety requirements, apply effective phytosanitary treatments for steri markets and, as a result, expose them to fewer risks and losses.


3


4

1 Delegates attend a session at the CRI Citrus Symposium.
2 Keith Lesar, the extension officer responsible for post-harvest technology transfer in the CRI Extension Department.
3-4 Thanks to the Post-harvest Diseases of Citrus manual, employees can now correctly identify fruit infections at all the critical points along the cold chain. The images show *Diplodia* stem-end rot on a navel orange [3] and sour rot on soft citrus [4]. Sour rot is caused by a fungus which occurs in the soil of all citrus production areas. Spores are spread by dust and water, splashing from the soil onto low-hanging fruit, and penetrate through damaged sections of the peel. The sour odour associated with the advanced stages of the infection attracts vinegar flies, which can further spread the fungus. Soft citrus varieties, such as mandarins, are particularly susceptible.

Supply Chain Logistics

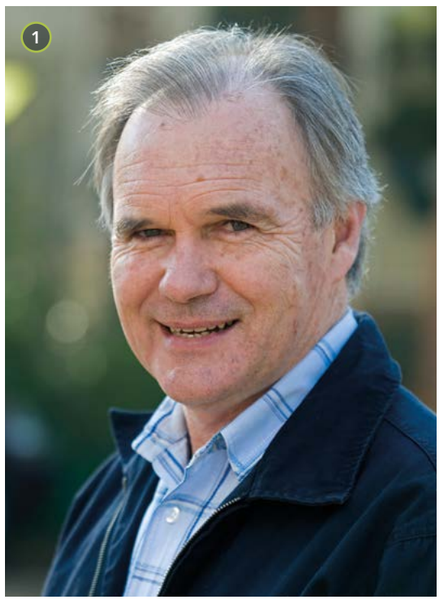
Follow the fruit, find the answers

In ancient times sailors believed ships disappeared off the edge of the world when they reached the horizon. The fate of South African fruit exports was pretty similar until international research cooperation illuminated the black hole.

Based on the study's findings, roughly 32 000 fruit shipments per year do not adhere to the PPECB protocols for temperature and humidity control.

THE SOUTH AFRICAN fresh fruit export chain is long. It takes up to 40 days for an apple to travel from an orchard in the Western Cape to a Sainsbury's shelve in the United Kingdom. Of that time, the fruit spends between 14 and 20 days on a ship at sea. This is, incidentally, the only part of the journey that is legally monitored.

In terms of the Perishable Products Export Control (PPEC) Act, vessels have to supply the Perishable Products Export Control Board (PPECB) with storage air temperature data for the duration of the voyage.



1 Prof. Malcolm Dodd.

Once the fruit arrives at the destination port, however, it disappears off the legal radar and, for all practical purposes, off the quality radar in general. What happens to our fruit when it arrives overseas and is sent to distribution centres, repacking facilities and later distributed to retailers? Up to a year ago, we simply did not know.

One of the biggest problems with this lack of insight into the final segment of the cold chain was who to blame when a consignment of fruit arrived in poor condition, especially when the fruit had no inherent quality issues on departure and the shipping records were satisfactory. Without answers, the cost and loss invariably ended up on the grower's account.

In 2011, cold chain expert, Prof. Malcolm Dodd, decided that the time was ripe for answers. The result was a research project made possible by unprecedented international cooperation.

THREE PLAYERS, ONE GOAL

Prof. Dodd persuaded two international partners, BT-9 Tech in Israel and Sainsbury's in the United Kingdom, to participate in a project with the Department of Horticultural Science at Stellenbosch University to scientifically monitor fruit quality throughout the supply chain.

The Post-Harvest Innovation Programme, HORTGRO^{Science} and Citrus Research International financed the South African part of the study. BT-9 Tech and Sainsbury's contributed their participation at no cost.

The aim of the project was to shed light on the 'hidden' parts of the supply chain – from when the fruit arrives at the overseas port to where it is sold. This involved gathering information on the relative humidity and the fruit pulp and storage temperatures in fruit export containers. Radio frequency identification (RFID) technology, consisting of data recorders, radio receivers and hand-held scanners, supplied by BT-9 Tech, made the study possible.

2 Refrigerated containers on a vessel in Cape Town harbour.

THE METHODOLOGY

The data recorders, known as tags, were inserted into two fruit pallets per shipment at the start of the journey. This was either in the pack house or the cold store, depending on the kind of fruit. The temperature and humidity information recorded by the tags was transferred by the radio receivers, via satellite, to a central server from where it could be accessed through the Internet.

The crucial overseas leg of the study was conducted by Sainsbury's staff. When the South African containers arrived at the distribution centre, the Sainsbury's team retrieved the cartons containing the tags from the pallets and made sure that these cartons were distributed to the supermarket.

In addition to the electronic tracking, two fruit quality control checks were part of the project design. The first samples were drawn by researchers from Stellenbosch University when the container left the farm.

The second quality control point was at the end of the supply chain where Sainsbury's staff collected samples in the stores. The fruit quality results were compared to the temperature and relative humidity data gathered by the RFID technology.

The study was conducted over two seasons, from December 2011 to December 2013, and examined plums, pears, apples and soft citrus as its test subjects.

THE RESULTS

The study successfully followed 22 shipments of fruit from pack house to point of sale. The data recorded showed that 14 shipments adhered to the export protocols. The soft citrus cold chain was largely up to standard, while the plum data revealed considerable room for improvement.

The study found that the weak links in the supply chain, from a temperature and relative humidity management perspective, were the container loading facilities, shipping containers, the receiving distribution centres (DCs) and the Sainsbury DC.

The good news is that no quality issues were recorded with any of the fruit from the shipments.

PROJECT TITLE
Radio Frequency Identification Technology (RFID) promotes understanding of the storage air, fruit pulp temperatures and relative humidity in a typical South African fruit export supply chain

PRINCIPAL INVESTIGATOR
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DURATION
Two years

PHI-2 CONTRIBUTION
R254 933

LEAD INSTITUTIONS
Stellenbosch University (Department of Horticultural Science), BT-9 Tech and Sainsbury's

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Supply chain logistics and information

PRESENTATIONS AND PAPERS DELIVERED
Two

Supply Chain Logistics

> "Simple attention to good cold chain practice by packing/loading operators and receiving distribution centres would improve the cold chain considerably."
> Prof. Malcolm Dodd

The bad news is that the cold chain appears to be riddled with variations.

"Our findings can be summarised in two words: consistent inconsistency," says Prof. Dodd. "And that is not good for delivering good quality product into the international market." For example, the team was left puzzled by these unanswered questions:

- Why do pallets in the same container experience vastly different temperatures?
- Why do some of the distribution centres not place the fruit in the correct temperature store?
- Why does relative humidity vary so much between the different kinds of fruit?

TOWARDS TRANSPARENCY

The benefits of this study extend far beyond the recorded data. Its contribution towards bringing transparency to the supply chain, particularly as far as addressing quality problems are concerned, cannot be overstated.

The data gathered gave the exporters and Sainsbury's a level of insight into their supply chain that they did not have before. Thanks to the project, companies such as Mack Multiples have started placing temperature data recorders in loads leaving their distribution centre.

Claims for losses can now be backed up with hard facts. As a result, innocent parties are protected and the culprits forced to take responsibility. The benefits for the insurance industry are self-evident.

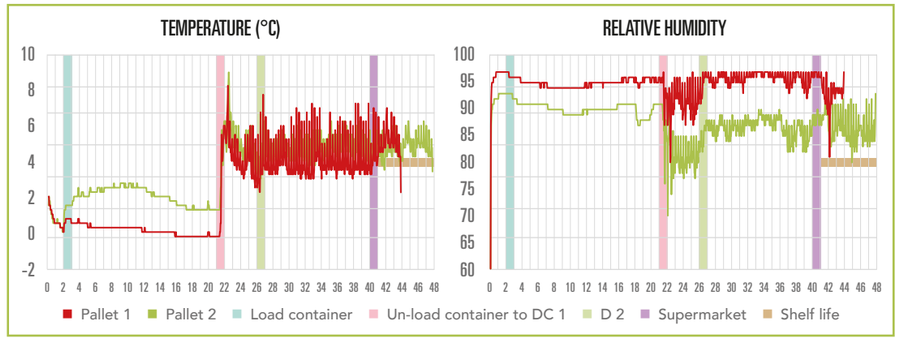
By using the radio technology that was proven in this study, fruit retailers can measure their service providers' contract specifications against facts and address any shortcomings. Sainsbury's has already used the research data to identify and rectify poor practices on the part of its service providers across the UK.

Arguably the most important benefit of the work done by Prof. Dodd and his team, is that the quality of fruit being offered to the export market can only improve as a result of better monitoring and management. The spin-off is a boost for 'Brand South Africa'.

"Our hope and intent is to use the results constructively," concludes Prof. Dodd. "We want to protect farmers by determining where the final responsibility lies when product losses are incurred, and want to establish who is legally accountable. Moreover, this international project should bring great value to the South African fresh fruit export industry."

1 BT-9 Tech radio-enabled fruit pulp temperature and relative humidity recorders in a carton of pears.

2 A container vessel, laden with refrigerated containers of fruit, on its way to distant markets.



The graphs show the temperature (left) and relative humidity (right) of two pallets of 'Angelino' plums shipped in the same container from a pack house in Ceres to a supermarket in the United Kingdom. The plums should be stored at 0°C and a relative humidity of >90% right throughout the 48-day supply chain. The vertical lines show the different stages (segments) of the cold chain.

> "Sainsbury's is delighted with the information that has brought transparency and allowed the identification of areas for improvement."
> Dr Theresa Huxley, apple and pear technologist, Sainsbury's

FRESH PRODUCE VALUE/ LOGISTICS/COLD CHAIN

Source: Prof. Malcolm Dodd

Supply Chain Logistics

Be cool, man

Easier said than done when you are a pear or a bunch of grapes en route from the farm to a supermarket in a foreign country. One break in the chain that holds your looks and flavour together and you could be heading for the compost heap instead of the kitchen table.

The quality of uncooled table grapes deteriorates more in one hour at 32°C than during one day at 4°C, or even a full week at 0°C.

Temperature is the greatest determinant of fresh produce deterioration rates and potential market life.

IT IS A DISTURBING FACT that a large percentage of the fruit harvested on farms goes to waste. Research findings for developing countries indicate that 40% of fruit and vegetables produced are lost due to poor post-harvest storage, processing, packaging, distribution and retail practices.

One of the biggest reasons for this, is a break in the cold chain – the series of refrigeration processes that slows down the rate at which fruit ripens so that it reaches the consumer in the best possible condition. The economic knock-on impact of an ineffective cold chain is potentially disastrous: unstable prices for local farmers and an uncompetitive export industry.

In South Africa, the Perishable Products Export Control Board (PPECB) governs the export of perishable products. Every year, the PPECB publishes protocols and procedures for the handling, storage and transportation of perishable products, with specific emphasis on optimum temperatures. For fruit, the prime indicator is pulp temperature, ie, how warm or cool the fruit's flesh is. The pulp temperature of apples and grapes, for instance, should be maintained at -0,5°C for the duration of their journey – from the farm and pack house to the consumer's shopping basket.

Despite the PPECB's best efforts, losses still occur. To understand the extent of and reasons for the problem, the Post-Harvest Innovation Programme joined forces with the CSIR and Stellenbosch University in a study that examined export cold chain practices in the Western Cape between June 2012 and October 2013.

Dr Esbeth van Dyk, principal supply chain analyst in the Transport and Freight Logistics section of the CSIR's Built Environment division, was the project leader. Working with her were Master's degree students and staff from the Stellenbosch University's departments of Logistics and of Horticultural Science. Four of the 10 largest exporters of deciduous fruit and table grapes in South Africa agreed to participate in the study.

1 Dr Esbeth van Dyk.
2 Good harvesting practices are the first link in an efficient cold chain.

THE AIMS OF THE STUDY

"Looking at summer fruit varieties that are exported in containers, we firstly wanted to determine the causes and the extent of breaks in the cold chain in order to minimise or possibly eliminate them," says Dr Van Dyk. "The study's second objective, and final outcome, is a Good Cold Chain Practice Guide to help the fruit industry improve operational procedures, reduce losses and improve the quality of export fruit." The guide will enhance the South African fruit industry's international competitiveness and reduce losses and claims, resulting in significant savings for both the industry and logistics operators.

HOW IT WAS DONE

The research team observed cold chain practices on fruit farms, in pack houses, in cold stores and at the Cape Town Container Terminal in the Port of Cape Town during the 2012/2013 summer fruit season.

In addition, the researchers conducted 12 temperature trials: one apple, two summer pear, three plum and six table grape trials from different production areas in the Western Cape and Northern Cape.

They placed temperature monitors in certain fruit cartons just after the pallets left the cold store to be loaded into the container. The monitors measured the fruit pulp temperatures and/or the ambient temperature and humidity throughout the container's journey to its overseas destination. The temperature data was e-mailed back for analysis. Although only 42 out of the 74 monitors were retrieved, valuable information was gathered.

PROJECT TITLE
Good Cold Chain Practice

PRINCIPAL INVESTIGATOR
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DURATION
16 months

PHI-2 CONTRIBUTION
R505 000

LEAD INSTITUTION
CSIR Built Environment

BENEFICIARY
The table grape and deciduous fruit industries

FOCUS AREA
Logistics

HUMAN CAPITAL DEVELOPMENT
Four Honours and two Master's degree students

PRESENTATIONS AND PAPERS DELIVERED
Five

PUBLICATIONS
One

In sub-Saharan Africa, it is estimated that as much as 20% of all fruit and vegetables produced are lost before they reach the consumer.

If one prefers to err on the side of caution and works on a 5% loss, in South African terms it means that about 12 290 tons of table grapes were lost in the 2011/2012 season. Given the season's average export price, the losses amount to more than R153 million.

For the purposes of the study, a break in the cold chain was defined as any rise in ambient temperature above 2°C for longer than 90 minutes.

THE FINDINGS

The researchers found several reasons for breaks in the cold chain:

On the farm

- Fruit is picked in high temperatures at midday.
- Picked fruit waits for a long time in high temperatures to be transported to a pack house.

At the pack house

- Insufficient shade at the receiving areas.
- High temperatures inside the pack house.
- Fruit is too warm when it is packed.

At the cold store

- Due to a lack of airlock loading bays, fruit is left outside under a roof while waiting to be loaded.

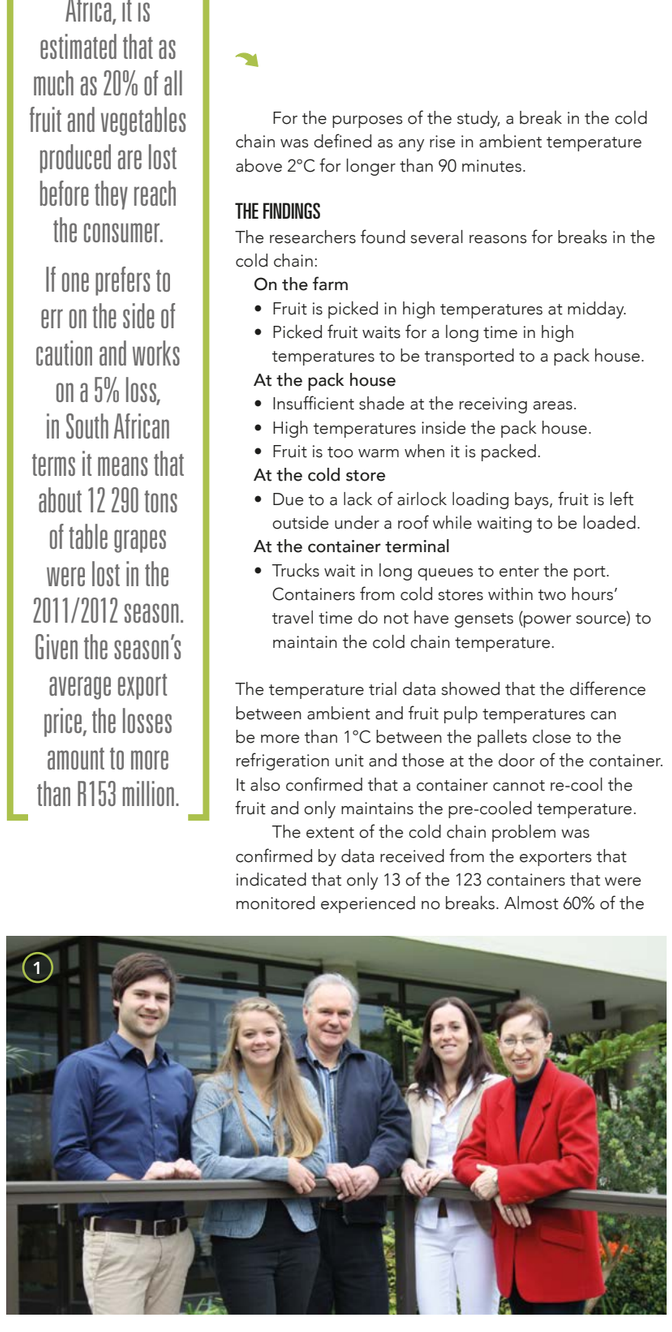
At the container terminal

- Trucks wait in long queues to enter the port. Containers from cold stores within two hours' travel time do not have gensets (power source) to maintain the cold chain temperature.

The temperature trial data showed that the difference between ambient and fruit pulp temperatures can be more than 1°C between the pallets close to the refrigeration unit and those at the door of the container. It also confirmed that a container cannot re-cool the fruit and only maintains the pre-cooled temperature.

The extent of the cold chain problem was confirmed by data received from the exporters that indicated that only 13 of the 123 containers that were monitored experienced no breaks. Almost 60% of the cold chain breaks happened at the interface between the cold store and the container truck, and 30% of the breaks occurred between noon and 16:00 – the hottest part of the day. More than 20% of the breaks continued for more than a day.

Dr Van Dyk says that the real solution to the cold chain challenge lies with people. "The cold chain will only improve once all the participants appreciate the impact of temperature on the shelf life of fruit and the important role they play in maintaining the cold chain." She is confident that the Good Cold Chain Practice Guide will play a role in this process.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THE LINKS IN THE COLD CHAIN

The fruit export cold chain starts the moment the fruit is harvested. The freshly picked fruit is pre-cooled in a refrigerated room to remove the field heat – a crucial step to preserve the quality of the fruit.

The pre-cooled fruit is transferred to the pack house where it is sorted and packed. The next stop is the cold store where the packaged fruit is cooled rapidly to its optimum storage temperature (eg, -0,5°C for table grapes) and then kept refrigerated at this temperature until the road trip to the port from where it will be exported. If the load will spend more than two hours on the road, the PPECB prescribes that is has to be transported in a refrigerated (reefer) container, fitted with a generator set or in a refrigerated truck.

Once the load reaches the port, the containers are stacked in a reefer container yard and plugged into electrical power points. Containers are usually stacked according to the sailing schedule and loading plan of the vessel they will be exported on. Once on board the vessel, the containers are plugged into the vessel's electrical power supply.

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1 The research team members are (from left) Heinri Freiboth, Laura Haasbroek, Prof. Malcolm Dodd and Dr Leila Goedhals-Gerber (all from Stellenbosch University) and Dr Esbeth van Dyk from the CSIR.
2 On the farm: Fruit is sometimes picked in high temperatures and wait for a long time to be transported to a pack house.
3 The Good Cold Chain Practice Guide is a valuable educational tool that reiterates the importance of keeping fruit cool, thereby adding to its quality and shelf life.
4 At the pack house: Fruit is often too warm when packed, either due to insufficient pre-cooling or high temperatures inside the pack house.
5-6 At the cold store: An airlock loading bay keeps the cold chain intact. Where cold stores do not have airlocks, the fruit is often left outside under a roof while waiting to be loaded.
7 At the container terminal: Trucks often wait in long queues to enter the port. Containers from cold stores within two hours' travel time do not have gensets to maintain the cold chain temperature.

Supply Chain Logistics

When standards stack up

An innovative pallet testing device can save the South African fresh fruit industry millions of Rands and spur the development of stronger, cheaper pallets.

$

A pallet costs about R100, but can support a shipment of about R10 000 worth of fruit.

SOUTH AFRICA is a major player in the global fresh fruit market – in 2012, it was the second largest exporter of citrus in the world. The country's annual fresh fruit exports have averaged about R14 billion over the past five years.

Exporting such a large quantity of quality fresh fruit would not be possible without pallets – flat, usually wooden structures that can be forklifted into trucks and refrigerated containers. Fresh fruit destined for overseas markets are packaged in cartons that are then stacked on pallets.

A pallet's journey across the globe is a rough and bumpy ride. It must withstand cartons weighing more than a ton, forklifts flying in at different angles, being dragged across pack house floors and thrown around in moving trucks.

"A pallet costs only about R100, but it is entrusted to support thousands of Rands worth of fruit," says Koos Bouwer, an industrial engineer and independent engineering consultant. When a pallet breaks, the cartons buckle or collapse, damaging the content. Not only does the damaged fruit have to be sold at half price on the local market, but valuable time is wasted to repack the fruit.

Mr Bouwer estimates that only about 15% of South African fruit pallets are of a poor standard. "But 15% of three million fruit pallets exported each year is a large number."

Whenever pallets break the pack house and the pallet manufacturer point fingers at each other. The pack house claims poor quality, while the manufacturer blames rough handling in the pack house.

Up to now, this blame game could not be resolved. There were neither standards that a pallet had to conform to, nor a practical way to test such standards.

THE NEED FOR A TESTING DEVICE

Prior to October 1997, Outspan regulated the South African citrus export industry and Unifruco the deciduous fruit sector. The two exporters' packaging design departments coordinated the design and testing of fruit pallets.

Following deregulation, which allowed anyone to register as an export agent, no organisation fulfilled these functions. The design drawings of fruit pallets currently in circulation date back to the period of regulation and don't specify the forces a functioning pallet must withstand.

PALLETS IN THE PAST

Pallets evolved from skids – flat wooden boards with two runners like a sleigh – that were used to move cargo from shore to ship. The skids were carried by hand and loaded onto ships using a winch.

Pallets are first mentioned in documents dating back to 1931. However, the first known patent for a pallet was issued to two Americans, George Raymond Sr and Bill House, on 7 November 1939.

The patent for the modern-day forklift truck was issued on the same day. Allegedly, the pallet was invented specifically to promote the use of the forklift truck. Raymond's iron foundry would become the Raymond Corporation, a global provider of forklifts.

The logistical requirements of the Second World War led to the widespread use of pallets during the 1940s.

Since 1998, the height of the shipping containers in which pallets are transported have increased from 2,1m to 2,4m. As a result, pallets have to support up to 15% more weight than in the past, but the design drawings have not been adjusted to accommodate the extra load.

In 2008, a collaborative study between the Fresh Produce Exporters' Forum (FPEF) and the Commonwealth Secretariat (Comsec) made several recommendations for improving the logistics of the South African fresh fruit export industry. One of these recommendations stated that new packaging standards should be set and all packaging formats should be updated, including pallets.

In 2009, the Agricultural Research Council funded a project to develop pallet standards aimed at improving the quality of South African export pallets. With the pallet standards established, the next step was to build a practical testing device to test whether pallets conformed to these standards.

BOUWER TO THE RESCUE

In 2012, the Post-Harvest Innovation Programme tasked Koos Bouwer to design a pallet testing device to be used by pallet manufacturers and pack houses.

PROJECT TITLE
Pallet test equipment

PRINCIPAL INVESTIGATOR
Koos Bouwer

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DURATION
Nine months

PHI-2 CONTRIBUTION
R140 000

LEAD INSTITUTION
Koos Bouwer Consulting CC

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Supply chain logistics

HUMAN CAPITAL DEVELOPMENT
One BEng student

1 Koos Bouwer.
2 The pallet testing device ensures that all South African export pallets adhere to the highest standards.

Supply Chain Logistics

1654: The first orange and lemon trees in South Africa are planted in the gardens of the Dutch East India Company in Cape Town. The trees came from the island of St. Helena.

1925: South Africa exports more than a million boxes of citrus for the first time.

The device was designed with practicality in mind – it is compact, economical and easy to operate. Considering the amount of money it could save, it sells at an affordable R38 000. It is also cheap and easy to maintain. "The device only has two components you can't buy at your local hardware store," says Mr Bouwer.

The device is operated manually and uses no electrics, software, hydraulics or pneumatics. No more than two people are required to operate the device, which is easy to calibrate and, therefore, suited for semi-skilled workers.

Gert Coetzee, an engineering manager from the fruit packaging company, Kromco Ltd, says he is happy that a prototype proved that Kromco's self-made pallets are of exceptional quality. "Pack houses should test the quality of their pallets, because the 15% rubbish that enters the market gives South African fruit exporters a bad name."

LOOKING TO THE FUTURE

Now that the functional requirements of pallets are known and can be tested, pack houses cannot blame manufacturers for broken pallets if those pallets have passed the tests. Pack houses and farmers can also demand that manufacturers test their pallets before they are sold.

The testing device is also breaking new ground in pallet design. There is a growing trend towards plastic pallets, which can be cheaper, lighter and pose fewer health risks than wooden pallets. In 2010, for example, Pfizer had to recall several of its over-the-counter products that had been contaminated by a chemical applied to the wooden pallets.

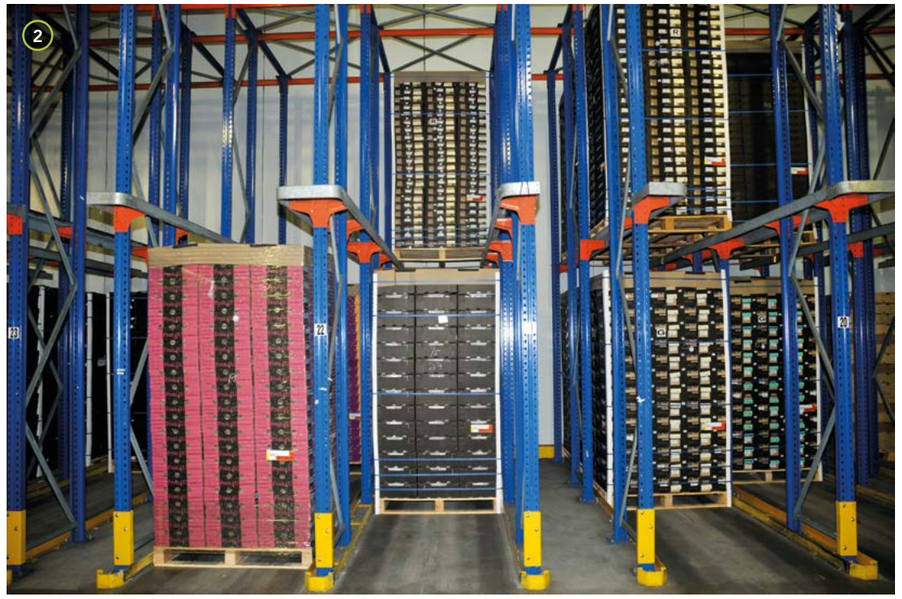
Despite these advantages, expensive tests slow down the development of new plastic pallet designs. According to Mr Bouwer, his pallet testing device paves the way for optimal pallet designs, including plastic, which could increase the competitiveness of South African fruit exports.

In 2014, Mr Bouwer will deliver several presentations at seminars and industry association meetings, and train staff at manufacturing facilities, pack houses and logistics depots on how to use the pallet testing device. He will also train industry players on how to use, interpret and update the functional pallet specifications for the five major fruit groups.

THE DEVICE AT WORK

The pallet testing device, designed by Koos Bouwer, performs seven different tests to confirm that a pallet is up to standard. These tests are grouped into three categories.

LOAD-BEARING TESTS	IMPACT TESTS	DROP TEST
The bending stiffness test simulates the load a pallet carries while resting on a pallet rack in the cold store. If used for citrus, it must be able to resist 1 300kg without distorting by more than 20mm. The vertical pull test pulls the top part of the pallet upwards and the bottom part down to test the resistance of the pallet joints. Forklift bending test	The impact tests mimic the force of a forklift hitting the pallet blocks at 1,27m per second. This simulation is achieved by forks attached to a pendulum that slams into the stationary pallet. The height at which the fork hits the pallet is adjustable, which makes it possible to test different types of impacts. There are three impact tests: • Block impact test • Top-edge impact test • Shear impact test	The final test drops the pallet on one of its corners from a height of one meter.



Citrus: Oranges, grapefruit, lemons and limes. Naartjies and mandarins are soft citrus.

Deciduous fruit: Table grapes, apples, pears, peaches, plums, kiwifruit, nectarines, persimmons and apricots.

1 A pallet designed to hold citrus must be able to resist 1 300kg without distorting by more than 20mm.
2 Exporting large quantities of quality fresh fruit would not be possible without pallets.
3-6 It is estimated that only 15% of South African fruit pallets are of a poor standard. But 15% of the three million fruit pallets exported each year is a significant number.

Green Chemistry

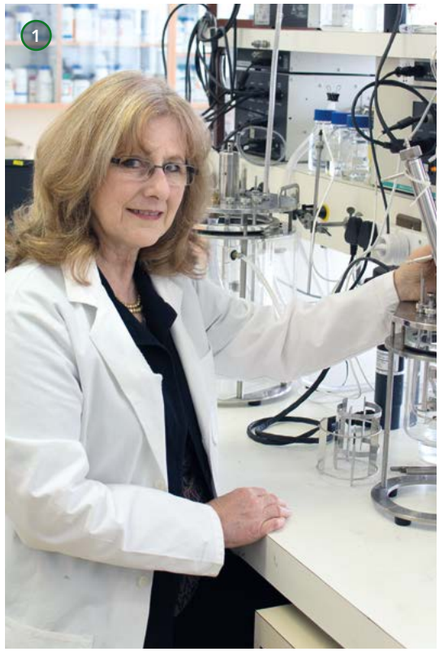
The good, the bad and the ugly

Mould on fruit and vegetables is bad. The aggressive, destructive fungi causing it are ugly. Enter *Bacillus subtilis*, the hero that rescues fresh produce from death and decay.

> "It is only by connecting specialists in various fields of expertise that a synergistic solution to a highly complex problem can be achieved."
> Prof. Kim Clarke

EVERY YEAR, the perishable produce industry experiences considerable post-harvest crop losses. It is estimated that as much as 50% of the harvested crops are lost worldwide. Much of this is due to decay caused by microorganisms that produce post-harvest diseases.

Some of the most aggressive and destructive plant pathogens, *Botrytis* spp. (affecting table grapes) and *Penicillium* spp. (affecting citrus) induce diseases such as grey mould and black rot on table grapes, and anthracnose on strawberries, papayas, bananas, apples, potatoes, soya beans, tomatoes – indeed, almost all fresh produce can be affected. Fresh produce particularly susceptible to attacks by fungal pathogens, have high sugar levels, a high moisture content and low pH.



Effective disease control methods are essential to maintain food security. During the last decade, traditional treatment with synthetic fungicides has become increasingly undesirable due to the chemical residues they leave behind in the food chain. As a result, some of the most effective fungicides have been deregistered. Some of the pathogenic strains have also developed resistance to the fungicides.

Consequently, the need for green chemistry as an alternative to control fungal and bacterial post-harvest diseases, and to replace these commercial chemical compounds, has become more urgent in the agricultural sector.

Producers of export fruit are very aware of the increasing pressure from major export markets to fund ways of natural disease control.

HOW THE CHALLENGE WAS TACKLED

Prof. Kim Clarke, PhD in Chemical Engineering, put together a dynamic, multi-disciplinary team of specialists with expertise from life science and chemical engineering to investigate and determine the best way to produce a new bioproduct to control fruit and plant disease. Increasingly, the integration of engineering and life science disciplines is recognised as the key that unlocks the potential of new bioproducts to progress from the initial research stage to successful production and implementation. Prof. Clarke's team is uniquely competent to evaluate biological systems from a cross-disciplinary viewpoint. This enables them to consider the research challenges from multiple angles.

Internationally, consumer regulations and requirements demand that alternatives to current control methods be investigated. Prof. Clarke's search for the right bio-candidate led her team to the bacterium *Bacillus subtilis* for three reasons. First is its GRAS (generally regarded as safe) status. Second is its demonstrated control against post-harvest pathogens such as *Penicillium* and *Botrytis* spp. The third reason is that it produces the lipopeptide bioproducts, surfactin, iturin and fengycin, that exhibit antibacterial and antifungal properties.

"Our research focused on the production of bioproducts from a bacterial (*Bacillus*) culture and the development of the bioproducts as an environmentally friendly alternative to current control strategies," says Prof. Clarke.

Until recently, research done on the *Bacillus*

PROJECT TITLE
The production of antimicrobial lipopeptides by *Bacillus subtilis* for biological control of post-harvest spoilage organisms

PRINCIPAL INVESTIGATOR
Prof. Kim Clarke

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DURATION
One year

PHI-2 CONTRIBUTION
R190 909

LEAD INSTITUTION
Stellenbosch University (Department of Process Engineering)

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Green chemistry

HUMAN CAPITAL DEVELOPMENT
Two MEng students

PUBLICATIONS AND PRESENTATIONS
Six

1 Prof. Kim Clarke.
2 Phytopathogens on table grapes.

Green Chemistry

> "This research is novel in that it seeks to examine the application of the active bioproducts themselves, rather than using the entire *Bacillus* culture. In this way, it is envisaged to produce standardised and consistent bioproducts that, unlike the *Bacillus* culture, would be effective in any physical and chemical environment."
> Prof. Kim Clarke

culture was limited to the application of bacterial culture directly. By examining the metabolic bioproducts of the organism, the team has identified the potential value of these products to ward off disease in post-harvest crops. In essence, *Bacillus subtilis* acts as a natural microscopic factory of bioproducts that demonstrates the amazing ability to act as antibiotics or fungicides, fighting disease and decay.

"Our research is novel in that it seeks to examine the application of the active bioproducts themselves, rather than using the entire *Bacillus* culture. By doing this, we foresee the possibility to produce standardised and consistent bioproducts which, unlike the *Bacillus* culture, would be effective in any physical and chemical environment," explains Prof. Clarke.

In pursuing their objective, the team used microbiological and genetic procedures to isolate and identify the pathogens that cause disease in South African post-harvest crops. They then applied chemical engineering and biochemistry principles to produce, extract, purify and fractionate a cocktail from the *Bacillus* cultures that contained a wide range of bioproducts, many newly discovered, which were effective against the pathogens.

"We identified two *Bacillus* candidates that produce large quantities of antifungal lipopeptides," says Prof. Clarke. By applying various microbiological techniques, the researchers confirmed that, even with crude extracts, the bioproduct cocktail was effective against all the isolated pathogens.

"The bacterially produced bioproducts have considerable potential as an effective 'green' alternative for the control of diseases in post-harvest crops, either as a multi-product cocktail or as individual fractions, tailor-made for specific plant diseases," says Prof. Clarke.

1

PRACTICAL IMPLICATIONS

Biological control provides a safe and ecologically preferred alternative to chemical fungicides for the control of pathogens and reduction in post-harvest crop losses since these agents require a lower effective dosage and are biodegradable.

While the results of this research refer mainly to table grapes, the findings have significant implications for a wide range of perishable crops in the South African agricultural sector.

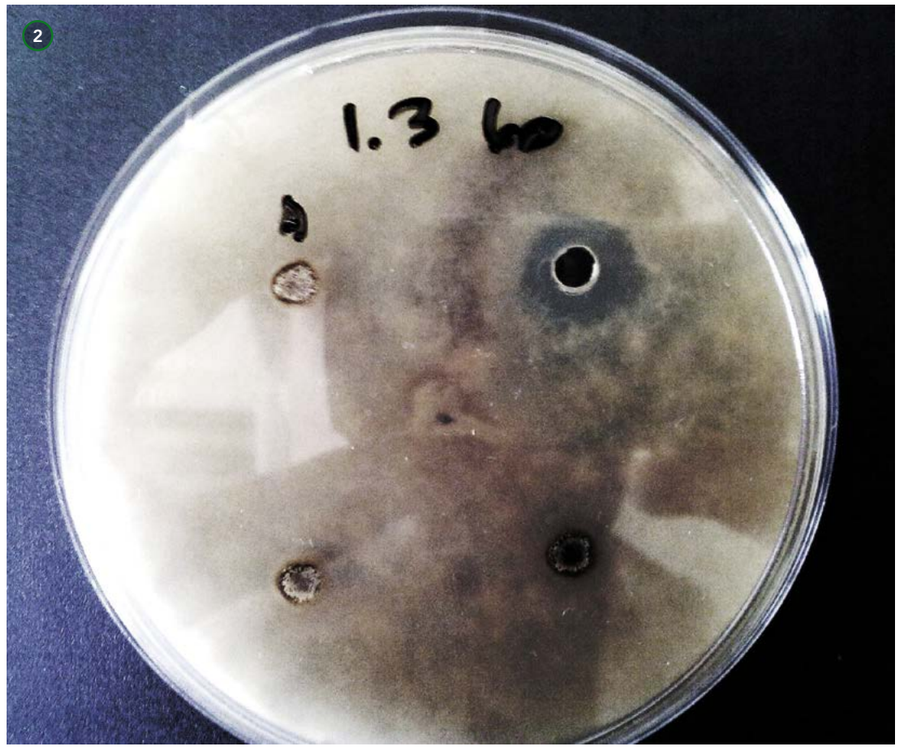
IMPACT ON THE PRODUCER'S BOTTOM-LINE

The successful production of this bioproduct can greatly reduce and even eliminate spoilage of perishable produce.

Process development would lead to enhancement of production performance and purification optimisation towards the implementation of the bioproduct as a preferred control strategy.

CONCLUSION

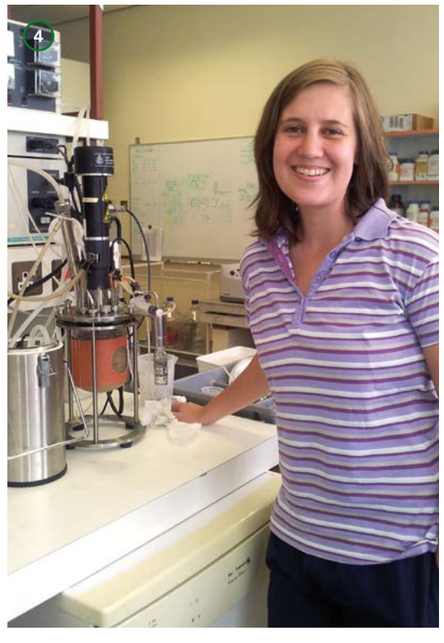
The bacterial production of lipopeptides, their extraction and purification from the bacterial culture and evaluation of their antagonistic activity against a range of phytopathogens causing disease in South African fruit has been investigated through an integrated approach, incorporating expertise from both engineering and life science disciplines. The findings to date suggest that the production and application of the specific bioproduct homologues to target pathogens will be a more definable, controllable and effective biocontrol strategy than direct application of the *Bacillus* culture, as was previously done.



2

> Research focused on the production of a bioproduct from a bacterial (*Bacillus*) culture and the development of an environmentally friendly alternative to current control strategies.

3



4

1 Manda Rossouw, an analytical chemist, determines lipopeptide amounts using High-Pressure Liquid Chromatography.
2 Agar plate showing an area clear of phytopathogens around top right well containing lipopeptides, confirming fungicidal activity. (Control wells on left.)
3–4 Jaco van Rooyen, a biochemist, and Daniëlle Pretorius, a chemical engineer, are members of Prof. Clarke's research team working with bioreactors that produce lipopeptides under controlled conditions.

Green Chemistry

There is life after DPA

Technology that monitors the oxygen levels in pears is a breath of fresh air in the quest to prevent superficial scald without the use of chemicals.

THE POST-HARVEST CHEMICAL, Diphenylamine (DPA), has been used widely in the South African pome fruit industry since the 1960s to control the skin condition called superficial scald.

It has been the only control measure to be applied on 'Packham's Triumph' pears and apple varieties such as 'Granny Smith', 'Red Delicious', 'Cripps Pink', 'Cripps Red' and 'Golden Delicious'. Its anti-scald activity is the result of its antioxidant properties, which prevents the oxidation of alpha-farnesene (involved in the development of superficial scald in fruit) to MHO (6-methyl-5-hepten-2-one), and the subsequent development of brown skin discolouration during storage.

A recent change in European Union (EU) regulations now allows only minimum traces of DPA on export fruit. From March 2014, the maximum residue limit (MRL) allowed for DPA is 0,1ppm for both apples and pears destined for export to EU markets.

This is part of the EU's drive to eliminate all post-harvest synthetic chemical treatments on imports, due to health and environmental risks. The anti-DPA stance is understandable, given that it was initially developed to keep rubber stable, and its derivatives are still used as anti-ozonantsor protective agents in the manufacture of rubber products.

When discussions on possible new regulations for DPA use started, South African apple and pear exporters had to re-look their export strategies. An option was to find markets other than Europe or Russia for their produce, but since 60% of all pears grown in South Africa are exported to these destinations, it was clearly not the preferred option. The alternative was to explore replacements for DPA, so that these lucrative markets can still be accessed without fear of produce being turned away at customs.

As far back as 2008, the Agricultural Research Council (ARC) Infruitec-Nietvoorbij started developing strategies to find alternative ways of preventing scald. Kobus van der Merwe led the project, supported by HORTGRO Science.

Dynamic Controlled Atmosphere (DCA) storage technology emerged as an appealing option, because it is non-chemical and uses existing controlled atmosphere (CA) technology. The Post-Harvest Innovation Programme provided further funding to draw purposeful conclusions on what the minimum exposure period is in the use of DCA to control superficial scald on pears.

Dr Filicity Vries, a senior researcher in the Post-harvest and Wine Technology Division of ARC Infruitec-Nietvoorbij, leads the project with the assistance of Mr Van der Merwe. Prof. Linus Opara, South African Chair in Post-harvest Technology at Stellenbosch University (SU), Dr Elke Crouch of the SU Department of Horticultural Science, and an MSc student in Horticultural Science at SU, Melrose Ramokonyane, are collaborating on the project.

The team members set out to investigate the effectiveness of DCA fluorescence-based technology to reduce the development of superficial scald during long-term storage and to maintain post-harvest pear quality and shelf life.

1 Pears stored in dynamic controlled atmosphere remain firm and are deliciously tasty and fragrant once ripe.
2-3 Pears with scald and without scald.

CA VERSUS DCA

"The main thing we are controlling is the oxygen levels in existing CA rooms," explains Ms Ramokonyane, who is in the process of writing up the results of the studies for her MSc thesis.

She says that DCA and CA storage are similar, in that both maintain quality by storing products in a gas-tight container that controls temperature, oxygen and carbon dioxide concentration and relative humidity.

DCA technology uses fluorescence detection sensors to dynamically control the atmosphere. It makes the storage of fruit at its lowest respiration rate possible. The sensors measure the amount of fluorescence light emitted by the fruit's skin, allowing operators to pin-point the anaerobic point. This is an essential parameter in determining the minimum level of oxygen to be maintained in the room during storage. "Simply put, the pears' 'breathing' tells the operator when and by how much to reduce the oxygen levels in the storage rooms to preserve fruit quality without causing superficial scald," says Ms Ramokonyane.

With DCA, it is possible to create ideal conditions for the medium to long-term storage of fruit, as it allows the operator to lower the oxygen levels in storage rooms without the risk of hypoxia and correlated physiological disorders. It is thus possible to set and adapt the values of gases in a dynamic manner, based on the maturity, climatic variations, different origins and varying respiration rhythms of the monitored fruit.

WHAT IS SUPERFICIAL SCALD?

Superficial scald, also known as storage scald, is a physiological disorder of apples and pears. Scald appears as irregular brown discolouration of the skin of the fruit, severely affecting the external appearance. This can reduce the acceptability of the produce for the fresh fruit market. Symptoms develop after cold storage during the shelf life period.
Source: Washington State University

PROJECT TITLE
Dynamic Controlled Atmosphere (DCA) as a practical technology

PRINCIPAL INVESTIGATOR
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DURATION
One year

PHI-2 CONTRIBUTION
R276 020

LEAD INSTITUTION
ARC Infruitec-Nietvoorbij

BENEFICIARY
The deciduous fruit industry

FOCUS AREA
Green chemistry

HUMAN CAPITAL DEVELOPMENT
One MSc student

PUBLICATIONS AND PRESENTATIONS
Three

> "The main thing we are controlling is the oxygen levels in existing controlled atmosphere rooms."
>
> Melrose Ramokonyane

CONDUCTING THE RESEARCH

The research was done in the DCA storage facilities of ARC Infruitec-Nietvoorbij in Stellenbosch. 'Packhams Triumph' and 'Forelle' pears from the Grabouw and Ceres production areas in the Western Cape were harvested at optimal maturity and subjected to storage at:

- CA ('Packham's Triumph' 1,5%O_2/2,5%CO_2; 'Forelle' 1,5%O_2/0-1%CO_2);
- DCA ('Packham's Triumph' DCA + 1%CO_2; 'Forelle' DCA + 0-1%CO_2); and
- Regular air (RA) (control).

The storage regimes were tested for four, six and eight months. The next stage was a four-week RA (shipment period) for the CA and DCA fruit, followed by a shelf life period of zero, seven and 14 days at 20°C. Quality evaluations were conducted after zero, seven and 14 days for each treatment according to industry standards. The experimental layout was a completely randomised design with a factorial layout. The factors included two areas, two storage regimes, three storage periods and three shelf life periods.

THE RESEARCH RESULTS

The research has led to key findings that can be put into practice by pack houses:

- DCA technology effectively inhibits superficial scald on pears for up to eight months in storage.
- It maintains the post-harvest quality of the fruit through increased firmness retention and better skin colour retention at shelf life conditions.
- DCA-treated pears can only be kept on the shelf for up to seven days.
- DCA inhibits scald by suppressing the oxidation of alpha-farnesene to MHO.

MAINTAINING A COMPETITIVE EDGE

"DCA technology extends the storage life of pears for up to eight months and it effectively inhibits superficial scald on 'Packham's Triumph' pears," summarises Dr Vries. "It is a cost-effective alternative as producers and exporters only have to install the DCA software to continue using existing CA rooms."

DCA technology helps fruit from South Africa to retain its quality and it prevents superficial scald development. As a result, South Africa can maintain its competitiveness on the global market."

> "This technology helps fruit to retain its quality and prevents superficial scald development, which helps South Africa to maintain its competitiveness in the global market."
>
> Dr Filicity Vries

SHARING KNOWLEDGE

The European Union's decision to lower the permitted residue level of DPA for export pears has sparked efforts to find alternative post-harvest treatments and to develop new storage technologies.

At ARC Infruitec-Nietvoorbij, the search for new alternatives for the prevention of superficial scald has led to the testing of a cold storage technique called dynamic controlled atmosphere (DCA)

This technology will give the South African pome fruit industry a competitive edge by effectively reducing the use of DPA. Courtesy of DCA storage, it will be possible to store pears for extended periods without the development of any disorders. The resultant increase in fruit quality and extended shelf life, will help the local industry to maintain a competitive position in the global marketplace and remain a significant player in international trade

To transfer this new-found knowledge, reports will be presented at industry meetings and published in peer-reviewed scientific journals.

1 The research team members are (from left) Kobus van der Merwe, Vanessa Fortuin, Melrose Ramokonyane, Howard Ruiters and Dr Filicity Vries.
2 CA vs DCA: 'Forelle' pears benefit greatly from being stored in dynamic controlled atmosphere (DCA). The ripening process is inhibited (pear on the right) and shelf life is prolonged compared to the pear on the left that was stored in a controlled atmosphere (CA).
3 Melrose Ramokonyane shows the fluorescence technology that monitors the pears' oxygen concentration level and triggers an alarm when it reaches the point where anaerobic fermentation begins. Urged by the pears themselves, the operator then adjusts the temperature to inhibit ripening.

Green Chemistry

Green can also be mean

In the microbiological world, it is the job of 'good' microbes to keep the 'bad' ones under control. These miniature battles, which rage every day on the surfaces of the fruit we eat, have great potential for post-harvest disease control.

IN THE CITRUS and pome fruit industries, between 3% and 6% of fruit that is harvested in a typical season, decays mainly because of *Penicillium* rot. However, under favourable disease conditions, losses of up to 50% can occur in the post-harvest phase of fruit. These losses not only affect profit margins and initial input costs, they also eat away at retailer and consumer confidence in the marketplace.

The fresh fruit industry is therefore justifiably concerned about reducing the impact of blue and green mould. At the moment, producers rely on only a few post-harvest chemicals to protect fruit against the 'baddies'. Prof. Lise Korsten from the University of Pretoria's Department of Microbiology and Plant Pathology, however, is working on ways to expand the arsenal of weapons against the 'baddies' in a green way.

1 Prof. Lise Korsten.
2 Pears infested with green mould.

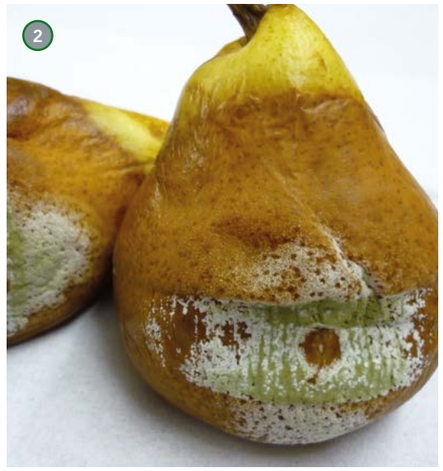
THE FIGHT-BACK

Like wily enemies, blue and green mould can defend themselves against fungicides. Under favourable conditions they proliferate rapidly to gain the upper hand. Producers often give the microbes a helping hand by following poor sanitation practices that result in a build-up of microorganisms that can infect the fruit later on, often at the end of the long export chain.

The mould's survival strategy also includes building up natural resistance against fungicides that are used regularly. Fungicide-resistant pathogens are a problem that has been detected in pack houses across the globe. To address it, the fruit industry has introduced hygiene management practices that include the use of a range of non-selective compounds and sanitisers. "But to be really effective, post-harvest disease management has to combine improved hygiene and sanitation practices with other disease control measures," says Prof. Korsten. "Our research is suggesting that pushing good microbes into the battleground through bio-control, green chemicals and best sanitation practices is the way to go. These greenies can also be combined or alternated with our existing arsenal of chemicals to manage and prevent the build-up of resistance."

Prof. Korsten adds that consumers across the world are increasingly concerned about human and environmental health and safety, hence the emphasis on going green. In response, researchers have intensified their efforts to develop new biocontrol products and low-toxicity compounds, also called soft chemicals.

Various bio-fungicides have already been developed and registered for the control of post-harvest diseases on fruit. "Although these agents show promise for commercial application, there are a variety of reasons, from questions about efficacy to customer regulations, why they have not been widely adopted," says Prof. Korsten. "The study my team and I undertook, evaluated the efficacy of different combinations of biocontrol agents and sanitisers against post-harvest fruit disease. Our aim was to develop an integrated disease management programme."



Two biocontrol agents were tested in the study. The first was a strain of yeast that occurs naturally on the surface of pears. The second was a product called Organisan II, which consists of a formulation of chitosan and yucca plant extracts. Chitosan, which consists of 75% deacetylated crab shells, has antimicrobial properties and prompts plants to deploy their own defence mechanisms.

IT'S NOT THAT SIMPLE

If a product is 'green' it has to be good, right? Not necessarily.

There are a variety of reasons for the slow uptake of green chemistry. In some instances, producers are reluctant to try something new when it comes to crop protection. Increased awareness and education can help to address this issue.

Another challenge is the difficulty to register bioproducts due to a lack of suitable regulations covering these novel products.

Market requirements can be a further potential barrier to trade. Sainsbury's in the UK, for instance, has a list of banned active ingredients that its producers are not allowed to use to spray crops.

As with inorganic chemicals, the green products need to be thoroughly researched and tested for all possible applications.

Penicillium was the pathogen targeted in the study. The project was done on-site in the Eastern Cape where the participating pack house made all facilities available and provided technical support. The research team used the microbiology laboratory at the University of Pretoria to identify the pathogens and to do *in vitro* trials.

DRAWING THE BATTLE LINES

The yeast test involved isolating dominant yeast colonies from the surface of a pear before and after it

PROJECT TITLE
The development and screening of alternative post-harvest disease control products and practices for citrus and pome fruit

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DURATION
One year

PHI-2 CONTRIBUTION
R131 513

LEAD INSTITUTION
University of Pretoria (Department of Microbiology and Plant Pathology)

BENEFICIARY
The citrus and deciduous fruit industries

FOCUS AREA
Green chemistry

HUMAN CAPITAL DEVELOPMENT
Three MSc and one BSc students

PRESENTATIONS AND PAPERS DELIVERED
Six

PUBLICATIONS
Two

Green Chemistry

> "We have proven the potential role that green chemistry can play in an integrated disease control approach."
> Prof. Lise Korsten

was placed in controlled atmosphere storage. Cultures of each of the isolates were prepared and propagated and then placed next to a spot of *Penicillium* spore suspension. The plates containing the isolates and the spores were incubated at 25°C and the researchers recorded measurements every day. The radius of the respective growths was used as a basis to determine whether and by how much the growth of the spores was being slowed down.

The Organisan II research was done on different citrus types both before and after the fruit has been harvested.

In the pre-harvest trials selected trees were sprayed with a solution of Organisan II. The fruit was then inoculated with a spore suspension of green mould and kept at 25°C for five to seven days to allow lesions to develop. Disease incidence and severity was noted. This experiment was done on 'Clementine' and 'Nova' mandarin oranges.

For the post-harvest investigation, the researchers selected and harvested unblemished and disease-free fruit that was export-ready. The fruit did not receive the usual post-harvest treatments, namely a warm fungicide bath and waxing. After being surface sterilised, the fruit was inoculated with a spore suspension of green mould (*P. digitatum*). The spore inoculation took place 12 hours before the Organisan II treatment was done as a preventative or 12 hours after inoculation for the curative approach. The trial was repeated under cold storage simulation circumstances where the fruit was kept for 21 days at 4,5°C

THE RESULTS

The researchers found that most of the natural yeast strains slowed down or prevented the growth of the *Penicillium* pathogen.

In terms of the Organisan II trials, the curative treatment of Organisan II on 'Midknight' Valencias and 'Clementine' and 'Nova' mandarins showed much less control of *P. digitatum* than the current commercial products. When it comes to preventative action, however, the treatment was more effective than the commercial fungicide application.

"I am satisfied that we have proven the potential role that green chemistry can play in an integrated disease control approach," says Prof. Korsten. "This project should be taken further to show the efficacy of new biocontrol agents and to ensure industry adoption of some of the new technologies."

Further studies will focus on integrated strategies for pome fruit and on biocontrol products in citrus pack house systems. The commercial value of this project is to develop new, integrated disease control strategies for the South African fruit industry to ensure product quality and safety.

> The commercial value of this project is to develop new, integrated disease control strategies for the South African fruit industry to ensure product quality and safety.

1 *Penicillium* up close and personal.
2 One affected fruit on an orange tree in the production chamber shows decay caused by *Penicillium*.
3 Pieter Louw, MSc student.
4 Prof. Lise Korsten and MSc student, SB Coetzee.

SPREAD THE WORD

The new knowledge of integrated disease control strategies that Prof. Korsten and her team have gained, has been transferred to the Eastern Cape citrus production region. New production practices have been shared with farmers of this region through pack house meetings. Additional knowledge transfer has been shared with the broader citrus community through a presentation at the Citrus Research International (CRI) conference. Research findings have also been shared with the international post-harvest community through an oral presentation at the International Post-harvest Conference in Stellenbosch.

Human capital development

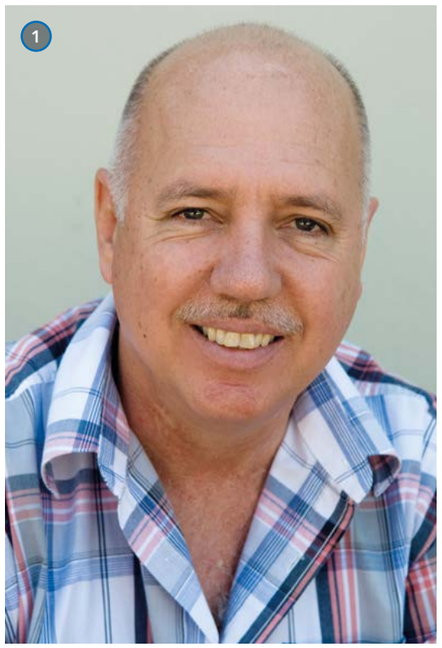
Unlocking the value chain

Growing and exporting fruit is the dream of many emerging farmers. Without dedicated and focused support, however, a fruit farm in experienced hands turns into a nightmare.

THE NEED TO TRANSFORM the South African fresh fruit industry is a pressing and legitimate one. But land reform in this country has not been particularly successful. To avoid repeating mistakes that have been made elsewhere, the Post-Harvest Innovation Programme has funded a two-phase project over the past two years.

The aim of the initial phase, done in 2012, was to support emerging farmers to become sustainable fruit exporters. With the help of Dawie Scholtz Consulting, the project assisted Lionel Martin of the Uitvlugt Farming Trust to export one container of 'Granny Smith' apples to UK retail agent, ASDA, in a direct export deal. This was done in cooperation with International Procurement & Logistics Ltd (IPL), the Fresh Produce Exporters' Forum (FPEF) and the Western Cape Department of Agriculture.

The second phase, conducted in 2013, revealed a number of stumbling blocks in the way to transform emerging farmers into successful and sustainable export farmers.



1 Dawie Scholtz.
2 Charles van Huffel and a team of workers on his peach and apple farm.

TWO TYPES OF FARMERS

Dawie Scholtz found that two categories of emerging farmer set-ups exist. The one is 100% black-owned emerging farms. The other is emerging farmers involved in equity schemes where the former owner was a commercial farmer who had created an empowerment trust with his workers. In general, these farmers have management agreements with the commercial partner and their fruit is exported through the commercial partner's export channel. "It would be foolish to interfere where these equity schemes are working well," says Mr Scholtz.

Maybe unsurprisingly, Mr Scholtz found that most of the dramatic failures in agriculture over the past 10 to 15 years happened to 100% black-owned farms. "Simply put: new farmers don't have the knowledge or capability to participate in the value chain. Our focus should be on helping these farmers to become successful exporters."

As a result of the research, the project's initial objective changed from assisting emerging farmers to export directly, to firstly helping them to optimise their potential. Before emerging farmers can meet the requirements for export, an environment of goodwill and coordination has to be created by role-players in the industry to meet the emerging farmers' unique needs.

For example, these farmers produce small volumes, often not enough to fill one container. They also need a lot of financial and administrative support and, above all, they need to learn about commercial processes.

The project involved 18 farmers. Each farmer's situation was investigated and understood and a solution sought with the farmer's input.

GROWING RESULTS

During 2013, a number of the participating farmers increased their production competency and added value to the marketing process by, for example, improving their food safety accreditation, increasing volumes and improving quality. Coordination with government and other funders were also streamlined.

Coordination with other industry role-players yielded promising results:

- Farmers in the Western Cape and Eastern Cape received technical assistance.
- Marketing assistance led to direct exports to overseas markets and sales to value-adding channels like local supermarkets (Freshmark) and processors (Boland Pulp). In cases where these farmers used to be limited to the hawker trade, they also benefited from higher hawker prices.
- The coordination of food safety accreditation resulted in four farmers applying for SA Gap Accreditation.
- Four farmers were helped to apply for Comprehensive Agricultural Support Programme (CASP) funding. Funding opportunities through the Land and Agricultural Development Bank of South Africa (Land Bank), Standard Bank and the Public Investment Corporation were also explored.

PROJECT TITLE
Assisting emerging farmers with fruit exports

PRINCIPAL INVESTIGATOR
Dawie Scholtz

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DURATION
One year

PHI-2 CONTRIBUTION
R360 000

LEAD INSTITUTION
DJ Scholtz Consulting

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Human capital development: small-scale farmers

Human capital development

To succeed, farmers need:

General assistance.

Business strategy support.

Help with funding applications.

Training and skills development to better understand markets, analyse results and interpret the business' financial position.

Some farmers registered for value-added tax (VAT) for the first time.

- Farmers reached a better understanding of their own businesses and thus a better chance at qualifying for funding. They are better equipped for success and are potentially more competitive. These interventions have also paved the way for future productive interventions in the emerging sector, with the focus on transfer of administrative skills and financial knowledge.
- Communication channels were established between the Department of Agriculture and other role-players, such as NGOs, service providers and academic institutions.

CHALLENGES REMAIN

Despite these successes, emerging farmers remain vulnerable to a variety of challenges, such as the lack of coordination. "Government is the main role-player but there is no central coordination from government," says Mr Scholtz. "As a result, the many consultants and other role-players that pursue uncoordinated objectives sometimes confuse the emerging farmers."The situation is aggravated by the fact that many of the farmers have had bad experiences with consultants in the past and are reluctant to trust them.

The process to achieve the necessary registration, such as becoming an FPEF member, is complicated and laborious. Global Gap Certification is also progressing slowly. Most of the farmers who have been certified did so with assistance from their packing/marketing channels. Farmers who do not market through formal channels are being assisted by the Perishable Products Export Control Board (PPECB) on an individual basis to obtain at least SA Gap Certification.

Many farmers simply do not have implements such as tractors and spray cars, ladders, picking bags and bins to pick their fruit, let alone vehicles to transport it. Good progress has been made with the provision of infrastructure and equipment through intervention of government and CASP funding.

Some of the smaller farmers required assistance with specific services that were arranged with, for instance, canners (Rhodes Food Group), pulping (Boland Pulp) and technical consultants (Michael Oosthuizen).

There is also good news. Many organisations and institutions showed goodwill and actively tried to help emerging farmers. Standard Bank, for example, introduced a programme for emerging farmers that might lead to cheaper financial assistance. Sonlia pack house offered discounted packing fees and Dole SA, the Freshmark supermarkets' supply channel, did not take a commission or charge a fee for its services. Franschhoek Marketing offered a discounted commission structure for the new season and a special marketing arrangement with a specific receiver in Europe. This willingness to support emerging farmers is only hampered by a lack of coordination and the basic ability of emerging farmers to operate at the level required of export farmers.

STRATEGIC HEADACHES

Several emerging farmers face strategic challenges: one farm is owned by 48 beneficiaries who have trouble communicating and coordinating; another operation is planning a merger with two other investors; and in some cases, economies of scale are simply not sustainable and will not be for the next 10 years.

All these farmers need specific and realistic business plans that are updated regularly. A decision was taken to integrate and coordinate business plans. In the Western Cape, only one business plan is done for every farm at present, and government uses the same business plan for funding applications. The process has also started in the Eastern Cape.

Dawie Scholtz's research confirmed that fruit farming on small units is challenging and in most cases not viable or sustainable. Wrong varieties, inefficient infrastructure, inefficient food safety accreditation and/or inefficient volumes are the main reasons why emerging farmers do not export successfully. However, in cases where they receive support from commodity groups, such as the Citrus Growers' Association of Southern Africa (CGA), HORTGRO and the South African Table Grape Industry (SATI), they do succeed in creating viable farms.

"Emerging farmers need more help than we had anticipated," says Mr Scholtz. "But they will succeed if we can build trust between them and the Western Cape Department of Agriculture, financing institutions and other role-players in the industry."

1 Trevor Abrahams (front left) and his workers – a proud new generation of export peach farmers.
2 Jan Damon shows a box of yellow cling peaches destined for the local market.
3 Lionel Martin inspects apples destined for ASDA in the UK.

Human capital development

Horticulture grows its own

Industry advancement depends on a constant inflow of skilled and knowledgeable people. Thanks to the efforts of the PMA Foundation for Industry Talent, the fresh produce sector's talent pipeline is growing.

To achieve its goals, the PMA hosted career fairs at Stellenbosch University and the University of Pretoria, to link prospective students to companies and organisations in the industry.

OVER RECENT YEARS, the inflow of qualified people entering the South African fresh produce industry has slowed significantly. Leaders in the industry and at South African universities have noticed a marked decline in the number of BSc students specialising in the fields of horticulture and agriculture. The result was fewer trained people in these fields and the amalgamation of university departments to ensure survival in the current economic climate. It was clear that the shortage of horticulture and post-harvest technology professionals was putting the country's economically important agriculture and export industries at risk. Small wonder then, that the fresh produce industry identified human capital development as its main priority. The PMA is an important partner in this quest.

1 Marianne van der Laarse.
2 Students and staff members at Potatoes SA's stand at the University of Pretoria Career Fair, which included a potato field!

WHO IS THE PMA?

The Produce Marketing Association (PMA) is a global trade association based in the USA. One of its prime tasks is to connect people across the international fruit and vegetable supply chain to network and share knowledge. It also creates marketing opportunities and facilitates opportunities for businesses the world over. Through its affiliate, the PMA Foundation for Industry Talent, the PMA supports industry-specific skills development.

The PMA became involved in South Africa in 2010, when Marianne van der Laarse was appointed PMA Country Representative. A country council, consisting of prominent business leaders and industry role-players, namely fruit and vegetable producers, marketers and retailers, was established to direct PMA activities in South Africa.

According to Ms Van der Laarse, the local branch of the PMA Foundation has three focus areas. The first is to address declining student numbers in the fields of horticulture, agronomy, soil science, plant pathology and entomology at universities. The second is capacity-building for students, teachers and lecturers in the post-harvest field of study. Finally, the PMA facilitates industry discussions on bursaries, internships and workplace experience programmes in the fresh produce industry. A future goal is to make more bursaries and internships available.

PEOPLE DEVELOPMENT IN ACTION

To achieve its goals, the PMA hosted career fairs at Stellenbosch University and the University of Pretoria during the past two years, to link prospective students with companies and organisations in the industry. "We have seen a remarkable increase in student numbers in agricultural sciences as a direct result of these fairs," says Ms Van der Laarse. "The next step is to encourage students to specialise in post-harvest disciplines."

The PMA Foundation found that short courses in post-harvest technology at the two universities play an important role in building capacity among lecturers, pre- and post-graduate students and private companies. To make the most of this resource, lecturers and post-graduate students from previously disadvantaged universities were invited to participate in a three-month post-harvest study visit to a hosting university. One of the lecturers, for example, visited the Stellenbosch University Food Science Department, while two students attended the Stellenbosch University Post-harvest Short Course in June 2013.

The PMA also presented industry-specific workshops. On 13 August 2013, about 40 people attended a workshop on industry internships. On 20 and 21 August 2013, a post-harvest technology workshop was held at the University of Pretoria to explore fresh produce and food safety, post-harvest technology and fresh produce packaging technology. Presented by local and international specialists, the workshop sessions have contributed to an increased focus on post-harvest technology and stimulated students' interest in the field. "The first post-harvest technology workshop took place in 2012," says Ms Van der Laarse, "and since then there has been a significant increase in the participation of students, lecturers and private sector companies in these events. Our workshops are important and effective vehicles of capacity-building in the post-harvest fields of academic study."

Communication with the South African fresh produce industry is a further priority for the PMA Foundation. PMA and PMA Foundation brochures, highlighting the PMA Foundation's activities in South Africa, were distributed at all industry events in 2013, starting with Fruit Logistica Berlin in February. Furthermore, the Foundation has used electronic media to market its career fairs and post-harvest technology workshops.

On 14 and 15 August, the PMA Fresh Connections Conference & Expo took place at the Lord Charles Hotel in Somerset West. Here, Margi Prueitt, Senior Vice President and Executive Director of the PMA

PROJECT TITLE
Building post-harvest capacity in the supply chain

PRINCIPAL INVESTIGATOR
Marianne van der Laarse

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DURATION
Two years

PHI-2 CONTRIBUTION
R600 000

LEAD INSTITUTION
PMA Foundation for Industry Talent

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Human capital development

PRESENTATIONS AND PAPERS DELIVERED
Three

Human capital development

> "With the initiatives that have been launched during the past two years, we have raised awareness of how 'alive with possibility' the agricultural industry is with careers for young people."
>
> Marianne van der Laarse

Foundation presented the results of an initiative funded by the Post-Harvest Innovation (PHI) Programme, which examined current employment trends in the South African agricultural sector. The study also identified the skills and training needed to address gaps in the fresh produce supply chain.

In the course of the past two years, the PMA Foundation has been consulting with the South African fresh produce industry to determine the current status of bursaries and internship programmes. "Our aim was to determine the available bursaries, how companies view internship programmes and which companies offer these programmes," says Ms Van der Laarse. "One of our aims is to create an easily accessible database of all the available bursaries."

The industry internships workshop, held on 13 August 2013, provided valuable insights on how the industry can increase the number of bursaries, internships and work experience opportunities available to students. Recent research has shown that these experiences influence the jobs students choose after they have completed their studies.

FRUITS OF THE PMA'S EFFORTS

The work done by the PMA Foundation and its affiliate in South Africa, has increased the awareness of human capital development issues in the agricultural industry since 2011. Exposure in the media (agricultural as well as mainstream media) has contributed to an understanding of the young, professional talent required in the agricultural field.

Companies and organisations have indicated that the career fairs have resulted in better bursary candidate recruitment. They were also finding it easier to identify bursary and internship candidates and potential employees.

There has been an increase in student enrolment numbers in the 'scarce fields' of study at the University of Pretoria and Stellenbosch University. Importantly, the career fairs and information sessions have opened teachers' eyes to agriculture as a career option for learners.

The work done by the PMA Foundation in South Africa has established a successful platform for industry discussions on topics related to human capital development in the local fresh produce industry, and will continue to do so.

WHAT STILL NEEDS TO BE DONE

The initiatives and projects that were launched at the universities of Pretoria and Stellenbosch have drawn positive responses from the industry, the participating universities, students and school learners. These initiatives need to be extended to other tertiary training institutions, including previously disadvantaged universities. Schools programmes must also be expanded to reach school children before they make career choices. This is not a short-term approach, and will require substantial investment from industry, government and tertiary training institutions to help attract young people to the agricultural sector. In addition to attracting talent, comprehensive resources will be required to train, develop and retain young people for the industry.

1-2 Curious students gather at the Dutoit Group stand, while staff members from Westfalia share their enthusiasm for careers in agriculture at the career fair, held at Stellenbosch University.
3 Delegates and speakers at the successful Post-Harvest Workshop, held at the University of Pretoria in August 2013.
4-5 The career fairs provide opportunity for students, lecturers and industry representatives to network, and to learn more about each other's worlds.
6 Cheerful students enjoy apples and tomatoes at the University of Pretoria Career Fair.

Information and Communication Technology

Point, click and find

Thanks to Agri-Intel's powers of systemisation, agrochemical information is no longer a confusing jumble.

AGRICULTURAL CROPS, be they grains, vegetables or fruit, need human intervention to grow strong and healthy. One of the main priorities of every farmer is to protect the harvest. In this mission, agrochemical products play an important role. But knowing what products to apply when and how is no simple matter. From growth regulators to fungicides, pesticides and herbicides, the selection alone can be bewildering. Add to that the fact that one wrong choice can mean the loss of an export contract, and the process becomes truly daunting.

Farmers who produce fruit for export have to comply with a range of different requirements of destination countries and retailers in terms of maximum residue levels (MRLs), pre-harvest intervals (PHIs) and retailer-specific conditions regarding agrochemical use. Producers can also only use registered, legally permitted products that are safe and suitable and comply with the latest regulations.

When producers base their crop protection action on incorrect or outdated information, the financial and market access consequences can be dire.

1 Kobus Hartman with Chana-Lee White (left) and Sarah le Grange.
2 The Agri-Intel website features flexible, web-accessible search and reporting mechanisms to retrieve the MRL, PHI and retailer-specific agrochemical information it stores.

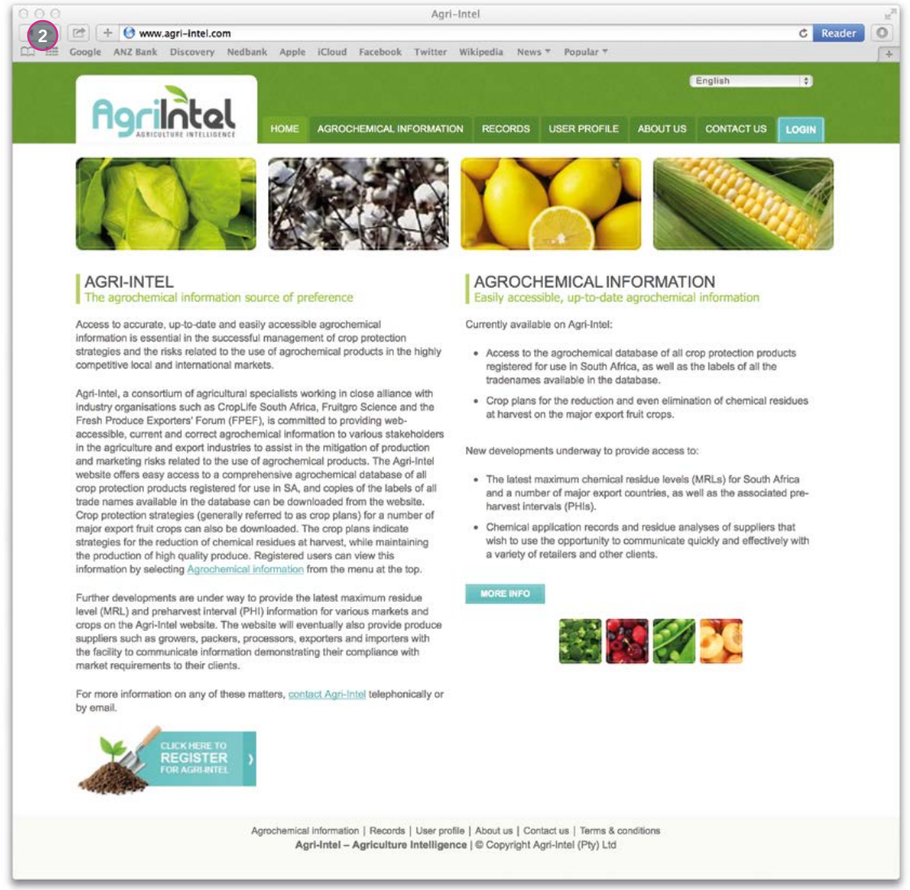
FIRST STEPS

As far back as 2007, Capespan Exports (now Capespan South Africa) established a website as part of the Agri Business Systems international (ABSi) initiative to meet the demand for a single source of information on agrochemical and other market requirements. It was an electronic communication platform that published information on international fruit export standards and requirements, and allowed producers to reciprocate with proof of their compliance with these standards.

But the need for a streamlined communication system that included a consolidated source of agrochemical information extended to the entire food crop and agrochemical industry. Consequently, CropLife SA, the association that represents manufacturers and suppliers of crop protection products in South Africa, contributed funding to expand the ABSi chemical database. It was eventually decided, however, to maintain ABSi as a Capespan in-house service, and to establish another platform to serve the entire fruit export and broader agricultural industry.

In 2012, Kobus Hartman led a PHI-funded project, initiated by the South African Agrochemical Database Consortium, to develop a fully-fledged web portal that houses an expanded, consolidated, web-accessible chemical information database of all the agrochemical products registered in South Africa.

It was envisaged to be a crucial resource for role-players in agricultural production and marketing,



PROJECT TITLE
Developing a consolidated, continuously updated and web-accessible South African agrochemical database (first call) and Developing flexible, web-accessible search and reporting mechanisms to retrieve the stored agrochemical information (second call)

PRINCIPAL INVESTIGATOR
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DURATION
One year + one year

PHI-2 CONTRIBUTION
R250 000 (first call)
R170 000 (second call)

LEAD INSTITUTION
South African Agrochemical Database Consortium

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Information and communication technology

Pre-harvest intervals (PHIs) refer to the time that has to pass between the last application of a pesticide and when fruit can be harvested for safe, immediate consumption. In other words, the withholding or safety period between application and harvest necessary to comply with the MRLs for the chemicals applied.

such as producers, food packers and processors, producer bodies or associations, exporters (including the Fresh Produce Exporters' Forum), importers, auditors, local and international retailers, agrochemical companies and their representatives, as well as CropLife South Africa and its associated bodies. It was also intended to assist regulatory stakeholders, including the Department of Health, the Department of Agriculture, Forestry and Fisheries (DAFF), analytical laboratories and certification bodies.

"One of the key features of the first phase of the Agri-Intel project was that it consolidated agrochemical information from various sources into one, easily accessible database," says Mr Hartman. "It is still the only source of agrochemical information of this magnitude and scope in South Africa."

SOURCING THE INFORMATION

An important source of this information is the labels of registered agrochemical products. Since these labels are legal documents, it is of the utmost importance that the information is interpreted correctly and, where necessary, clarified with the registration holder. This not only meant that the Consortium had to maintain expert knowledge, but also required prompt communication between it and registration holders.

Upon the completion of the first phase of the project, the Consortium had met its objective to establish an accurate, verified, comprehensive and continuously updated online South African agrochemical database in English and Afrikaans.

Information on the maximum residue levels allowed by importing countries was gleaned from the websites of the European Union, the Environmental Protection Agency in the USA, CODEX and sites carrying information on export destinations such as Russia and the Far East. South African PHIs are indicated on product labels, but a variety of industry sources had to be consulted to determine export destinations' intervals.

This information was published for the main export fruit types (citrus, pome and stone fruit, and table grapes) in PDF format, as insufficient funding was available to develop a full-scale database and reporting mechanisms for the MRL, PHI and retailer information components.

The PDF format meant that the database was not searchable; users could not query a set of data, or narrow down a search to isolate specific information or effectively compare sets of information. Also, information was outdated until the next PDF was published and downloaded by users. Enter Phase 2.

BUILDING AN INFORMATION HIGHWAY

From February to November 2013, the Consortium focused its efforts on developing flexible, web-accessible search and reporting mechanisms to retrieve the MRL, PHI and retailer-specific agrochemical information stored in Agri-Intel.

"Our vision was to give Agri-Intel users the ability to run efficient and directed searches and to easily compare MRL and PHI information in terms of different crops, agrochemicals, markets and retailers," says Mr Hartman. "These tools were needed to achieve the website's ultimate purpose, which is to assist in decision-making and to reduce the risk of non-compliance."

By the end of 2013, the software development and testing had been completed. This included the database, an administration facility and reporting mechanisms to query and obtain results from the information in the database. Data had also been imported, tested and verified.

In terms of the fresh fruit industry, Agri-Intel now contains complete data for pome and stone fruit, table grapes and citrus in terms of MRL requirements in South Africa, the European Union, America and Russia; PHIs and information on UK retailers' residue levels requirements and preferred chemicals.

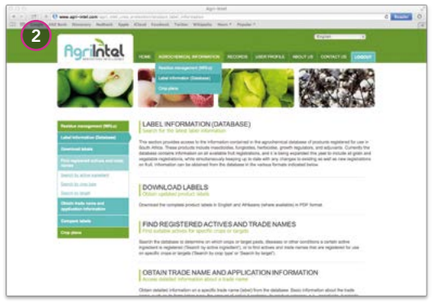
Apart from providing information, the Agri-Intel website also facilitates one-on-one communication between local fresh produce suppliers and international markets. Suppliers can upload their spray records and residue analyses results. Certificates are also available for downloading and viewing by specific, designated retailers.

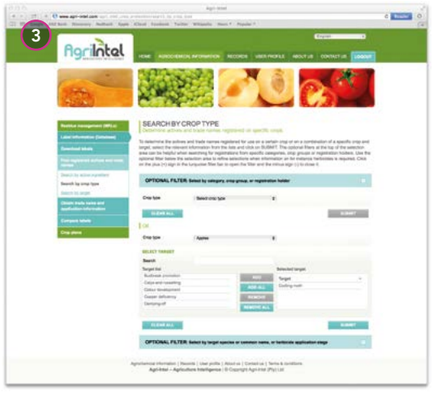
"We have quite literally moved from a dirt track to an autobahn when it comes to access of information," says Mr Hartman.

THE ROAD AHEAD

In this age where information is generated and changed in the blink of an eye, the value of a website depends on the quality and frequency of its updates. "This remains a challenge for us," says Mr Hartman. CropLife currently funds one permanent position for the maintenance of the database content, but funding is needed for website hosting and administration, further database maintenance and quality control, and further software development.

"There is so much more we can do," says Mr Hartman. "For example, offering specialised services on a user-pays basis could turn Agri-Intel into a sustainable business."





AS EASY AS W-W-W

Agri-Intel provides an agrochemical database that is:

- **Easily accessible** via the Internet.
- **Consolidated** – all critical label information, MRLs and PHIs are in one location.
- **Always accurate** – unlike printed material, it is continuously updated and remains relevant.
- **Flexible** – can be queried and filtered, because it is not only static documents.

A WEALTH OF INFORMATION

- Almost 2 000 registered chemical labels (trade names).
- More than 500 active ingredients.
- Agrochemical information on all the regulated raw agricultural commodities of plant origin, such as fruit, vegetables, grain, forestation, flowers and ornamentals.
- Labels of insecticides, fungicides, herbicides, adjuvants and growth regulators.
- Information on registered targets, eg, the particular pests, diseases or weeds controlled by specific products.
- Registered dosages.
- Information relating to the application of the products.

Maximum residue limits (MRLs) are the maximum traces of agrochemicals that are allowed to be on food. These limits are set by international bodies such as the European Union (for EU countries), the Environmental Protection Agency (for the USA) and relevant authorities in other countries. The purpose of MRLs is to protect consumers against overexposure to pesticides, fungicides and other chemicals used to protect crops.

1-4 The series of screen shots shows the steps a user will follow to draw a report on the products that are registered to control codling moth on apples. The process culminates in a comprehensive report.

Information and Communication Technology

Proudly doing the right thing

The local fresh fruit industry is the first in the world to benchmark its ethical practices against global standards. With an almost perfect score, our customers can proudly buy South African.

> "Our customers want to be confident that the people who make and sell our products are not being exploited, or exposed to unsafe working conditions. Our Code of Conduct for Ethical Trade covers the employment practices we expect from our suppliers, both in the UK and abroad."
>
> J. Sainsbury plc

EXPLOITATIVE LABOUR PRACTICES in some developing countries have tarred the rest with the same brush. South Africa did not escape the fallout. Consumers in many countries, including the United Kingdom and European Union, have been demanding that international retailers verify the ethical compliance of South African agricultural suppliers. The local industry rose to the challenge under the guidance of the Fruit South Africa (FSA) ethical trade programme, and achieved a world first by subjecting its ethical standard to the Global Social Compliance Programme (GSCP) equivalence process.

1 Colleen Chennells.

ONE STANDARD FITS ALL

The GSCP has as its members many international retailers, including Tesco, Wal-Mart, Migros, Ahold, Carrefour, COOP, Marks & Spencer and Sainsbury's. It collapses several ethical codes into a single reference tool and avoids duplication of ethical audits. Local retailer, Pick 'n Pay, is now also a member of the GSCP.

Various international codes were included in creating the GSCP reference code. These included the ETI Base Code (used in the UK), the BSCI Code (mainly used by European retailers), and SA 8000 (the only accredited certification standard for social accountability).

In addition, the GSCP provides reference tools for audit methodology and auditor recognition.

THE LOCAL JOURNEY

FSA set the ethical trade programme in motion in 2008. FSA is supported by its member organisations; the Fresh Produce Exporters' Forum (FPEF) and the fruit growers' associations - HORTGRO, the Citrus Growers' Association of Southern Africa (CGA), the South African Table Grape Industry (SATI) and the South African Subtropical Growers' Association (Subtrop). Together, they represent approximately 5 000 producers and 400 000 employees. The FPEF has around 112 members, of which the majority are export companies. The organisation is also the official Fresh Fruit Export Council of South Africa.

The FSA ethical trade programme has now been formalised as the Sustainability Initiative of South Africa (SIZA). SIZA is the custodian of the industry-wide ethical standard that is recognised by many large international retailers.

The SIZA Standard is based on International Labour Organisation (ILO) conventions and South African labour legislation. One of the biggest advantages of this development is that the SIZA Standard and audit replace the multitude of ethical standards and audits that existed before.

To promote awareness and understanding of the ethical trade programme and standard, the FSA Ethical Trade Handbook was published in 2011. It is also available electronically on the ethical trade website: www.siza.co.za. While the standard is formal and exclusively focused on legal requirements and benchmarks, the handbook is more practical and explains the evidence required to demonstrate compliance with the law during an audit. For example, employment contracts and pay slips are necessary to prove wage rates or deductions. The handbook covers a wide range of topics, such as terms of employment, benefits, wages, loans, overtime conditions, working hours, pregnancy and maternity conditions, discrimination, harassment and abuse, housing and accommodation, training and skills development and broad-based black economic empowerment.

The handbook and website, which are available to all fruit growers, facilitated the implementation of the ethical standard in South Africa.

The ethical standard is separate from any food safety standards and requires its own process of determining compliance. It is important to remember that participation in the fruit industry's ethical trade programme is voluntary. However, it is designed to support fruit growers with compliance and ongoing improvement and the approach is positive and constructive. The programme also supports training to raise awareness and encourage participation on grounds that it will benefit the business and reduce risk to individual businesses and the overall industry.

SIZA is a membership-based programme. All producer and pack house members subscribe to the ethical standard and agree to participate in the programme cycle of training, self-assessment, third-party ethical audit, and correcting of non-compliances to promote continuous improvement of working conditions on farms. Support of continuous improvement is the core element of the South African ethical trade programme. The ethical audit is not about passing or failing, but about identifying issues on farms, and helping farmers to address problems with the appropriate resources. For example, extension officers will be trained to help farmers prepare for the ethical audits. The idea is to use the structures that are already in place – if an extension officer is already serving a particular farm, the ethical code training will supplement his work.

Although developed by the fruit industry, the SIZA standard is aligned to South African legislation and can therefore be applied to the entire local agricultural sector.

INTERNATIONAL BENCHMARKING

FSA chose to use the GSCP reference code as the platform for its own ethical standard as it contains all the principles of the ETI Base Code, the BSCI Standard and the SA 8000 Standard and it was an important platform for endorsement by major retailers.

CONTINUED SUPPORT

The SIZA capacity-building programme will run more than 70 workshops throughout South Africa in 2014 and 2015 to train over 1 500 ethical trade facilitators. They will then provide producers and pack houses with the necessary support to implement the SIZA Standard.

For more information on SIZA, visit www.siza.co.za

PROJECT TITLE
An international ethical standard for South Africa

PRINCIPAL INVESTIGATOR
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DURATION
Seven months

PHI-2 CONTRIBUTION
R170 000

LEAD INSTITUTION
HORTGRO

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Ethical trade: ethical audits

SIZA – the isiZulu word meaning to help and support – embodies the underlying ethos of the programme.

Moreover, it supported the principle of convergence and non-duplication of audits.

FSA received funding from the Post-Harvest Innovation Programme and the Department of Trade and Industry (dti) to develop the SIZA Standard and audit process documents, and to carry out the GSCP benchmarking and equivalence process.

The objective of the project was to first align the South African ethical standard with South African legislation, and then to benchmark it against the GSCP reference code.

Buy-in from the fruit industry was necessary to achieve this goal. The first step, therefore, was to consult fruit producers, exporters, the FPEF, HORTGRO, the CGA, SATI, Subtrop and other relevant role-players.

The next step was self-assessment to measure the standard's equivalence against the GSCP Reference Code. The result was submitted to the GSCP for review against its rating system, where blue equals more than equivalent, green equivalent, amber partially equivalent and red not equivalent. An assessment by an international working group found that the South African ethical standard and reference tools on auditing methodology were almost 100% equivalent to the GSCP Reference Code and tools.

The long-term vision of the SIZA programme is to implement the South African standard on all local fruit farms and to expand it to other industries. The programme works with various stakeholders, including the Department of Agriculture, Forestry and Fisheries, the Department of Labour, the Department of Trade and Industry, worker organisations, retailers, importers and exporters, to provide the necessary support, network and infrastructure in the different production regions.

The fruit industry is committed to the national implementation of an ethical standard. It will benefit the entire industry by giving farmers the means to provide the international market with the assurances it requires through a single auditing process.

THE SIZA ADVANTAGE

Producers and pack houses benefit from membership, because SIZA:

- Consolidates retailer requirements and eliminates the duplication of ethical audits.
- Is South African-based, reflects local legislation and is specific to local agriculture.
- Provides producers with information to improve on-site working conditions through the analysis of self-assessments.
- Applies a rating system that helps to identify areas of risk.
- Provides support to prepare for audits.
- Offers a data system that analyses self-assessments and audit results and gives a clear picture of a business: areas of risk, what to correct and how to go about it, cross-reference to policies/documents, and areas of good practice.
- Can reduce audit frequency at low-risk sites.
- Runs a capacity-building programme that presents workshops for SIZA members, as well as toolkits and other resources, at no additional cost.
- Can prevent assurance schemes from being imposed on the industry in the future.

"The South African fruit industry is the first to undergo the Global Social Compliance Programme (GSCP) equivalence process that benchmarks a local agricultural social standard against international ethical requirements. This endeavour was the catalyst for the establishment of the Sustainability Initiative of South Africa (SIZA)."
Colleen Chennells

1 Sorters work at speed to sort avocados for export. SIZA aims to help improve working conditions on fruit farms and in pack houses in South Africa.
2-3 Participants work in groups during workshops that are part of a Leadership and Mentorship (L&M) programme, funded by International Procurement & Logistics Ltd (IPL) and Tesco, to build management and leadership skills in the workplace through a mentoring process.

Information and Communication Technology

Sign on the digital line

Paperless offices may continue to elude us, but a project initiated by Paltrack has proven that the fruit export supply chain is ready for online documents and electronic signatures.

> 4
>
> At the moment, each intake and dispatch document is either printed on special four-layered paper or multiple copies are printed.

MORE THAN R500 000 PER YEAR. That's what it costs the fruit export industry to print intake documents. And that is only ink and paper. Now add the costs associated with handling the documents, such as couriering, faxing and filing. Not to mention the paper-induced productivity losses.

The good news is that there is a better way and it has been proven.

Andries Mouton, managing director of Paltrack, led a 10-month proof-of-concept project for an electronic signature and document management solution for the fresh fruit export industry. Paltrack supplies software solutions to the industry, including pack-line management, label and document generation and warehouse and stock management systems.

1 Andries Mouton.

"Because we have clients all along the supply chain, from the farmer to the export agent, we have a bird's eye view of the process and the paperwork involved," says Mr Mouton. "We identified electronic signatures, backed by an integrated electronic document management solution (EDMS), as the next step towards increased competitiveness. Our goal is a real-time value network where all trading partners can easily connect and share information."

The electronic signature and document management project set out to show that by introducing document management technology, efficiencies can be gained, costs saved and the environmental impact of paper use reduced. The emphasis was on proving that electronic documents can and should be accepted as a legally binding alternative to their paper-based counterparts.

HOW THE PROJECT WORKED

Mr Mouton used the Paltrack software and systems related to intake and dispatch documents as point of departure. Based on the workflow from pallet intake to dispatch, the software engineers created a working prototype system that was implemented on Paltrack-sponsored hardware at various activity points. The prototype integrated Paltrack products with an EDMS and a signature solution. The EDMS solution is called PaperTrail and was sourced from Paltrack's original equipment manufacturer partner, EGIS.

"We chose the technology partners because they were close by, were willing to contribute and their products could be customised," says Mr Mouton. The Post-Harvest Innovation Programme funded some of the work needed to integrate the different products to create the overall prototype for proof-of-concept purposes.

The prototype was left to run 'live', but parallel with the existing paper-based approval and signing system.

As part of the project, the intake and dispatch documents were electronically presented to the people who usually sign them, including the Perishable Products Export Control Board (PPECB) inspectors and truck drivers. Instead of pen and paper, they signed the documents using a signature pad. The biometric information associated with the signing action was captured in the electronic document as a security measure.

The documents were then stored in an EDMS database at the pack house from where it could be distributed easily, immediately and cost effectively to all parties that require signed copies.

The team also created a cloud-based dummy PPECB database to show the potential for a central repository of all the inspection documents. The database was updated with signed documents within minutes of the inspectors having authorised them.

After a few days, the project team visited the sites to interview people who have used the prototype to get their feedback and recommendations. "We found that everybody who participated in the project, be they representatives from management, operations, information technology (IT), drivers or inspectors, welcomed the concept," says Mr Mouton. "People also saw that the technology could be applied in other areas of their businesses, such as human resources (HR), finance and contract management."

WHAT PARTICIPANTS LIKED

Once they understood the process and the reasons behind the technology, the inspectors, drivers and depot representatives were happy to use it. They found that there was much to like about electronic documents and signatures:

- **Speed.** The signed intake/inspection documents are delivered to the PPECB before the inspector leaves the site.
- **Quality and legibility.** No more struggles with printers that do not print clearly or faxed copies that are difficult to read.
- **Savings.** Less special order paper, printer cartridges and printer maintenance expenses.
- **Less frustration.** Fewer printer issues, especially paper jams, because of the significant reduction in the number of documents having to be reduced to paper.
- **Easy-to-use.** The users reported that the learning curve was not steep at all.
- **Saves time and effort.** One electronic signature is all it takes, and documents are sent automatically to the next depot, transport company or the PPECB.
- **Improved and more secure record-keeping.** Hard copies get lost, damaged or misplaced and take time to locate in even well-managed archives.

THE STUMBLING BLOCKS TO OVERCOME

Based on feedback from the participants, the project team identified the factors that could impact the implementation of the solution. Many of them were pilot system restrictions and can easily be resolved.

One of the concerns that were raised was that security validation consisted of only a login ID and a password. Mr Mouton says that the technology can provide real-time signature verification, but that the biometric information stored in the electronic version of a document provides all the information forensic auditors might need to determine who actually signed it.

PROJECT TITLE
Proof-of-concept for an electronic signature and document management solution

PRINCIPAL INVESTIGATOR
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DURATION
Ten months

PHI-2 CONTRIBUTION
R230 400

LEAD INSTITUTION
Paltrack (Pty) Ltd

BENEFICIARY
The entire fresh fruit industry

FOCUS AREA
Supply chain logistics & information

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The project findings show that EDMS can help to achieve efficiencies, reduce costs and create a 'greener' fruit export industry.

There are also several logistical factors to consider. For example, Internet connectivity, interruptions or power outages can hamper the electronic signing process, and set-up errors will result in documents being sent to the wrong location. The latter, however, also happens to paper documents that are manually handled.

An illustration of how easy the technology is to use, is the fact that the truck drivers' main complaint was that they had to walk to the dispatch office to use the signature pad that was linked to a PC there. Usually, they sign on a clipboard next to the truck. The 'sign-on-glass' technology that allows the signing process to happen on a mobile device next to a truck already exists but that was not part of this project.

The overall success of the project and the feedback from participants that EDMS can make a tangible difference, exceeded Mr Mouton's expectations. "We now have a number of solution evangelists out there. They have used the system we are proposing and are more than willing to share their experiences."

All that remains to be done is for the PPECB to endorse the proposed concept. This is necessary to find ways to accommodate the Department of Agriculture, Forestry and Fisheries' existing document requirements, for example, that original intake documents, bearing an inspector's signature and stamp, have to be submitted.

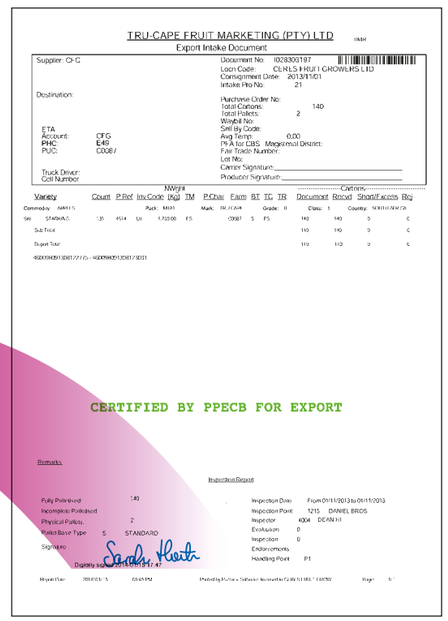
The project team believes that the legal considerations, security concerns, information ownership and privacy considerations have been, or can be, addressed. "If the pilot group's feedback is anything to go by, the industry is ready to go paperless," concludes Mr Mouton.

WHY IT CAN WORK

The proposed EDMS solution:

- is more secure than the current ink-on-paper system;
- leverages the technology to reduce cost and increase efficiency; and
- does not depart unnecessarily from the manual processes, making change management easier.

Electronic signature makes life so much easier and can even be more secure than ink on paper.



TRU-CAPE FRUIT MARKETING (PTY) LTD

Export Intake Document

Supplier: CI-G

Document No: 1028393197
Loan Code: CLIKLS FRUIT GROWERS LTD
Consignment Date: 2013/11/01
Intake Pro No: 21

Destination:

Purchase Order No:
Total Cartons: 140
Total Pallets: 2
Waybill No:
Sell by Code:
Avg Temp: 0.00
PHA for CBS: Magisterial District:
Fair Trade Number:
Lot No:
Carrier Signature:
Producer Signature:

ETA
Account: CFG
PHC: E49
PUC: C008 /

Truck Driver:
Cell Number

Variety	Count	P-Ref	Inv Code	Weight (Kg)	TM	P-Char	Farm	BT	TC	TR	Cartons: Declared	Recvd	Short/Excess	Rej
Commodity:				Pack:		Mark:		Grade:			Class:		Country:	
SW	STARKING	135	4514	1,710.00	FS		C0087	5	FS		140	140	0	0
Sub Total											140	140	0	0
Export Total											140	140	0	0

CERTIFIED BY PPECB FOR EXPORT

Remarks:

Inspection Report

Fully Palletised: 140
Incomplete Palletised:
Physical Pallets: 2
Pallet Base Type: S STANDARD
Signature:

Inspection Date: From 01/11/2013 to 01/11/2013
Inspection Point: 1215 DANIEL BROS
Inspector: 4004 DEAN H
Exclusion: 0
Inspection: 0
Endorsements:
Handling Point: P1

definitions

1. POST-HARVEST PATHOLOGY, FOOD SAFETY AND DISEASE CONTROL

Post-harvest pathology in the fruit industry involves the scientific study of post-harvest pathogens and fruit diseases to find remedies and solutions. It is closely linked to food safety and other issues of global importance. Green alternatives such as essential oils are now harnessed to combat post-harvest diseases. The microbial dynamics of fresh fruit is also investigated to develop fruit quality and safety guidelines and hopefully a standard for the industry.

2. MITIGATION TECHNOLOGIES FOR SANITARY AND PHYTOSANITARY COMPLIANCE

South Africa exports fruit to various markets that impose strict phytosanitary requirements to eliminate pests. Cold sterilisation treatments are effective, but not suitable for all fruit varieties. CATTS technology now provides a green mitigation alternative for quarantine pests, while special packaging formats are being developed to obtain certification in export fruit irradiation.

3. POST-HARVEST PHYSIOLOGY AND NON-DESTRUCTIVE FRUIT QUALITY ASSESSMENT TECHNIQUES

Post-harvest physiology in the fresh fruit industry concerns the scientific study of fruit after harvesting, with the goal of improving fruit quality and shelf life. In some cases it is required to induce fruit ripening, while cold storage treatments are generally aimed at delaying ripening to prolong shelf life. The influence of storage and other factors on the development of internal disorders are also determined. Non-destructive fruit quality assessment techniques are used in a study that provides insight into the mystery of mealiness in 'Forelle' pears and research shows when 'Triumph' persimmons should be harvested.

4. INTEGRATED PACKAGING SOLUTIONS

Fruit is a living, breathing organism that needs oxygen. Ventilated packaging plays an integral role in the maintenance of fruit quality, and is therefore one of the most vital elements of the fresh fruit export industry. 'Unpack the box' explains how exciting new technology – computational fluid dynamics – is used to design fruit export packaging.

5. CARBON FOOTPRINT / ENERGY EFFICIENCY IN THE SUPPLY CHAIN

Global warming and changes in climatic patterns have made the South Africa fruit industry aware of its carbon footprint, fossil fuel usage and the effect on greenhouse gas emissions. Considering the impact on the environment and constantly increasing electricity and fuel prices, practical solutions are required for the industry to remain socially responsible and globally competitive.

6. PRE-HARVEST DISPOSITION TO POST-HARVEST DISORDERS

The strict phytosanitary requirements of certain fruit export markets create numerous challenges for the South African fresh fruit export industry. In a new, internationally collaborated project, the Spanish citrus industry is helping to reduce chilling injury in our 'Star Ruby' grapefruit.

7. TECHNOLOGY AND KNOWLEDGE TRANSFER

In this book, technology and knowledge transfer is used as a generic term that describes the process of information, skills and knowledge transfer. Technology and knowledge transfer plays an important role in creating the necessary understanding of the South African fresh fruit value chain among relevant role-players.

8. SUPPLY CHAIN LOGISTICS

Logistics is an integral part of the South African fresh fruit export chain. It is imperative that the entire supply/value/cold chain functions efficiently – from pack house to the table – to ensure the smooth running of the export process. It is extremely important to manage product temperature and relative humidity efficiently in order to maintain fruit quality. An international project uses radio frequency identification technology to shed light on parts of the supply chain never monitored before. The compilation of a cold chain practice manual ensures that all stakeholders are equipped with a user-friendly reference guide. The value that high-quality pallets add to the prevention of losses is also highlighted in this focus area.

9. GREEN CHEMISTRY

The invention, design and application of chemical products and processes to reduce or eliminate the use of hazardous substances.

10. HUMAN CAPITAL DEVELOPMENT

Human capital development is one of the top priorities of the South African fresh produce industry. Specific initiatives are directed at students at schools and universities. They are receiving practical guidance on viable career choices in the agricultural sector to encourage skilled and qualified people to enter the industry. The focus is also on emerging farmers, in a pioneering mentorship intervention to help them develop into fully-fledged and sustainable fruit exporters.

11. INFORMATION AND COMMUNICATION TECHNOLOGY

An international ethical trade standard and a comprehensive and consolidated online web-accessible agrochemical database have been developed for South Africa. These two initiatives intend not only to benefit the entire South African agricultural sector, but also to be of international use. Another initiative to let the export chain run smoothly, focuses on electronic signature and document management.

POST-HARVEST INNOVATION PROGRAMME

a public-private partnership between

science & technology
Department: Science and Technology
REPUBLIC OF SOUTH AFRICA

fpef SOUTH AFRICA
Fresh Produce Exporters' Forum

www.postharvestinnovation.org.za