



Fact sheets GreenCHAINge

Vegetables and Fruit



WAGENINGEN
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Green Beans – brown discoloration

In GreenCHAINge an innovative 'smart chain' is being developed. Overall goal is to improve the intrinsic quality of the produce on the shelf.

Objective

Green beans are an important crop on the retail shelf. One of the main quality issues is brown discoloration during the post-harvest phase. The objective is to test what the causes are for this discoloration: 1) contact with free water, 2) low temperature and 3) microbial decay.

Results

Contact with free water does not increase the amount of brown discoloration, in fact the amount is lower. On the downside the beans that had been in contact with free water (washing or condensation) were limp (loss of firmness).

Low temperature did not increase the amount of brown beans. The beans stored at 18°C had most brown discoloration.

Microbial decay is not causing brown discoloration, since treating the beans with chlorine (not allowed in practise) had no effect.

The two used cultivars show a clear difference in amount of discoloration.

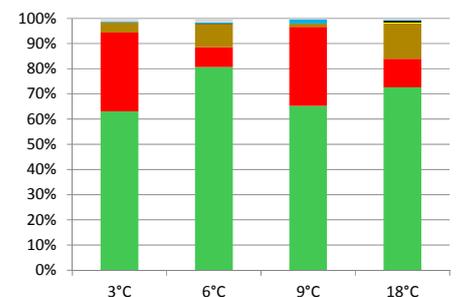
Conclusion

For prevention of brown discoloration the beans should be cooled below 9°C. Another measure could be to wash the beans, but the beans become more limp. Discoloration is partly cultivar dependent.

Relevant for industry

Keep the beans cooled throughout the entire chain until moment of purchase to minimise brown discoloration in beans.

"Maintaining temperatures below 9°C keeps green beans green"



Defect distribution in green beans for 4 storage temperatures: ■ intact beans, ■ limp beans, ■ brown beans, ■ small, ■ rot.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Green Beans – fresh cut

In GreenCHAINge an innovative 'smart chain' is being developed. Overall goal is to improve the intrinsic quality of the produce on the shelf.

Objective

Fresh cut green beans are an important crop on the retail shelf. One of the questions is how long fresh beans can be stored before being cut and packed without any quality loss during shelf life.

Results

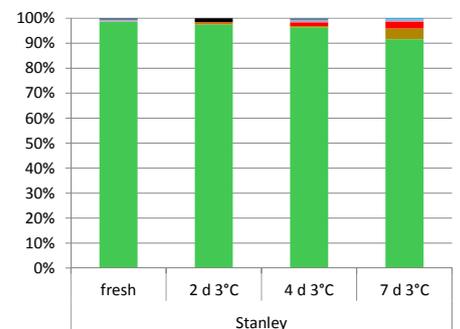
Fresh beans were buffered for 0, 2, 4 and 7 days at 3°C. The cultivar used for making cut beans "Stanley" can be buffered for 4 days and still have an excellent appearance. After 7 days, brown discoloration developed during the shelf life, but the beans remained acceptable. Longer stored beans gain more weight in the washing process.

Conclusion

Green Beans of the variety "Stanley" can be buffered for 4 days at 3°C without causing any quality loss during shelf life after cutting.

Relevant for industry

Fresh beans have a limited amount of storage time before they have to be processed. If they are stored too long before processing quality during shelf life will be impaired. The storage time is cultivar dependent.



Defect distribution after 7 days shelf life in cut green beans (cv "Stanley") for 4 storage durations before cutting and packing: ■ intact beans, ■ limp beans, ■ brown beans, ■ small, ■ rot.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Botrytis suppression in Grapes: high CO₂ versus SO₂

The growth of the fungus *Botrytis cinerea* is a key post-harvest challenge for the grape industry. Although SO₂ treatment is effective, it has several downsides. Substituting 12% CO₂ (for SO₂) appears promising, considering SO₂ treatment might soon be prohibited. This is the outcome of a research project, by Wageningen Food & Biobased Research, conducted within the GreenCHAINge project.

The growth of *Botrytis cinerea* in table grapes is a significant post-harvest issue. SO₂ is a very effective fungicide and slow-release SO₂ systems are routinely used in reefer-container grape transport. However, the negatives of SO₂ as a fungicide are serious: it accelerates corrosion, bleaches the fruit and certain consumers are allergic to the sulphite deposits. Crucially, SO₂ is legally forbidden for transport of organic grapes; good reason to search for alternatives. Explored within GreenCHAINge, an atmosphere of 12% CO₂ seems the most promising alternative to SO₂. Transport under higher CO₂ percentages would further suppress *Botrytis* growth, but would also increase the risk of adverse effects on quality such as off-tastes and browning.

Effects on grape quality

Wageningen scientists performed repeated lab experiments and field trials transporting grapes from South Africa to the Netherlands to determine if 12% CO₂ could be a viable alternative to SO₂. It is, and caused no damage or off-tastes.

Dry ice for atmosphere regulation

Controlled Atmosphere units cannot supply CO₂, and grape-respiration rates are low. So the container must be air-tight, or an additional source of CO₂ provided. Experiments proved that dry ice is a suitable source of CO₂. A patent application on this innovation has been filed.

Future perspective

The first commercial high-CO₂ shipments of organic grapes have occurred. For non-organic grapes SO₂ remains financially more attractive than CO₂. However, it is expected that measures will be taken to discourage, or even ban, the use of SO₂ as a (transport) fungicide. That would open a much broader application area for the use of dry ice as a source of CO₂ to prevent *Botrytis* growth during longer-duration grape transport.



Example of dry ice as a source of CO₂.



Assessing quality of grapes after transport from South Africa to the Netherlands (upon arrival at WFBR).

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Mango - effect of precooling and genset

In GreenCHAINge an innovative “smart chain” is being developed. Overall goal is to improve the intrinsic quality of the product on the shelf.

Objective

Obtain uniform and RTE (Ready to Eat) mangos on the shelf. Assess the effect of precooling mangos before transport, and the use of a genset during transport, on mango quality.

Results

When mango fruit is precooled fast (< 6 hours) the mangos remain firmer than fruit that is precooled slower. A significant firmness decrease from 81 to 77 on the acoustic firmness scale was observed when measuring firmness after transport to the Netherlands.

Using a genset (generator set) on the reefer container from the pack house to the port of Pecem in Brazil had no effect on firmness or any other quality parameter. This was found in two shipments in October and November 2016. A Prerequisite is that the mangos are precooled to transport temperature and the duration of transport to the port is not too long.

Conclusion

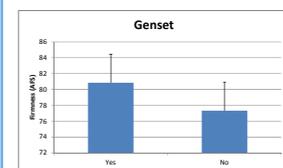
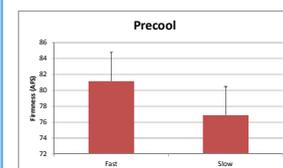
In order to maintain mango firmness before the ripening process mangos should be precooled within 6 hours.

Usage of a genset on the reefer container between pack house and port of Pecem has no direct influence on mango firmness.

Relevant for industry

Getting product to transport temperature is important to preserve initial quality.

“Using a Genset over relative short distances is not always necessary when mangos are proper precooled”



Average firmness of fast and slow precooled mangos (red) and average firmness of transported mangos using a genset (yes) or no genset (blue).

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Predict Mango quality by firmness

In GreenCHAINge an innovative “smart chain” is being developed. Overall goal is to improve the intrinsic quality of the product on the shelf.

Objective

Obtain uniform and RTE (Ready to Eat) mangos on the shelf. Determine the correlation of RTE mangos with “firmness”. Predict quality by measuring the firmness at day of arrival.

Results

Measuring the firmness of > 3000 mangos at different time points between harvest, transport from Brazil to the Netherlands and ripening, in nine shipments between Nov '16 and Jan '17, shows that firmness is a parameter to predict the RTE stage of Mango cultivar Keitt and Kent. Firmness at “day of arrival” at importer correlates with firmness of RTE stage mangos.

A protocol to predict RTE stage is available for both Keitt and Kent mangos based on:

- Firmness at day of arrival.
- Ripening at 16°C or 20°C.

Conclusion

Delivering uniform and RTE mangos on the shelf is possible by selection based on firmness at day of arrival at importer.

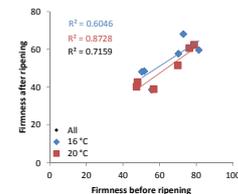
Relevant for industry

Measuring firmness pre- and post-harvest allows prediction of firmness at RTE stage resulting in a reduced variation. More uniform products allow more efficient handling of the product, less waste and delivery of better consistent quality to the final consumer.

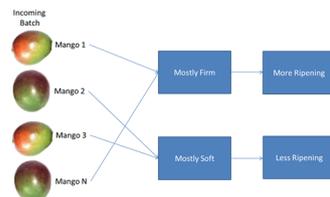
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“Selection based on firmness to deliver more uniform mangos”



Acoustic-firmness before ripening is a good predictor for RTE-STAGE and useful to sort mangos before the ripening process.



For detailed information about this project result please visit www.wur.eu/greenchainge.







Volatile biomarkers for Mango quality

In GreenCHAINge an innovative “smart chain” is being developed. Overall goal is to improve the intrinsic quality of the product on the shelf.

Objective

Obtain uniform and RTE (Ready to Eat) mangos on the shelf.
Obtain a non-destructive method to detect ripening/internal browning.
Correlate volatiles to the mango ripening or internal browning stage.
Use volatiles associated with internal browning as a biomarker.

Results

Volatile measurements of 36 Keitt mangos during the ripening process indicate that the profile of produced volatiles changes during ripening, particularly for volatiles of the ester family (known to cause fruity odours).

Measuring volatile production, internal color and internal defects of 50 Keitt mangos with low and high chances of internal defects shows that:

- Internal defects can be quantified using image analysis.
- The percentage of internal browning correlates with the production of volatile esters.

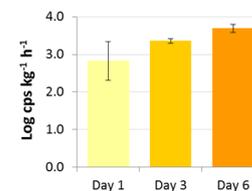
Conclusion

Ripe mangos produce more volatile esters and mangos that produce more esters show more internal breakdown.

Relevant for industry

Volatile esters may be used as a non-destructive biomarkers to detect over-ripe or brown mangos.

“Volatile esters may serve as biomarkers to detect internal defects”



Volatile analyses show an increase of esters during ripening (respectively 1, 3 and 6 days at 20 °C).

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Defected versus healthy Mangos

In GreenCHAINge an innovative “smart chain” is being developed. Overall goal is to improve the intrinsic quality of the product on the shelf.

Objective

Obtain uniform and RTE (Ready to Eat) mangos on the shelf. Compare and predict “defected” versus “healthy” mangos using non-destructive NIR (Near-infrared) measurements.

Results

Non-destructive NIR measurements using a FELIX-F750 handheld on approximately 100 “defected” mangos (with internal defects) and 100 “healthy” mangos, indicates that the NIR spectra can be divided in two separate classes.

Mangos can be classified as “defected” or “healthy”, based on their NIR spectrum, with an accuracy of 86% and standard dev. of 4%.

- A mango predicted as defected according to the NIR spectrum is truly defected 87% of the time.
- A mango predicted as healthy according to the NIR spectrum is truly healthy 84% of the time.

Conclusion

By analyzing differences in NIR spectra, mangos can be classified in “defected” or “healthy” fruit, by NIR measurements, with an accuracy of 86%.

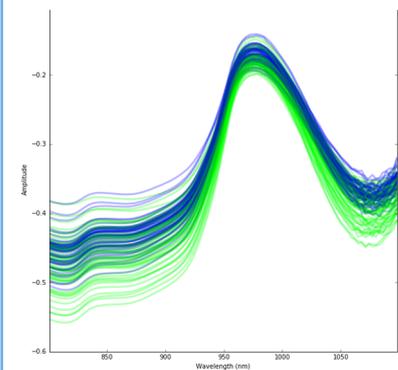
Relevant for industry

NIR measurements to non-destructively discriminate defected versus healthy fruit, ensures that only healthy mangos reach the customer. This leads to an increase in quality and efficiency, while lowering costs for all parties throughout the whole supply chain.

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“Measuring NIR spectra allows us to predict internal defects in a non-destructive way”



NIR spectra from defected (green) and healthy (blue) mangos, showing a distinction in two groups.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Mango quality and colour

In GreenCHAINge an innovative “smart chain” is being developed. Overall goal is to improve the intrinsic quality of the product on the shelf.

Objective

Obtain uniform and RTE (Ready to Eat) mangos on the shelf.
Determine the correlation of RTE mangos with “internal colour”.
Obtain an objective and reliable method to phenotype internal colour.

Results

Measuring the internal colour of > 3000 mangos transported from Brazil to the Netherlands, in 9 shipments between Nov '16 and Jan '17 shows that increased internal color (from class 1 (light yellow) to class 5 (dark yellow/orange)) correlates with:

- Decreased firmness.
- Higher ripening temperature.
- More internal defects/browning.

“Objective phenotyping” by automatically analyzing color pictures of standardized images, is reproducible and therefore more reliable compared to “subjective” division in five color classes. In addition, measurement of color pixels allows the use of a continuous scale which is more useful for data analysis.

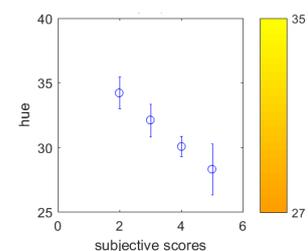
Conclusion

Internal color correlates with the ripening stage of mangos. This can be measured more precisely with an objective camera system.

Relevant for industry

Objective phenotyping allows standardisation of internal color assessments throughout the whole supply chain, reducing human bias and error. Data in a continuous scale allow correlations to NIR spectra.

“Objective colour measurements are more reliable and more useful for data-analysis”



Objective analysis by measurement of colour pixels (hue values), correlates with subjective observations by division from class 1 (light yellow) to class 5 (dark yellow/orange).

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Mango quality and internal defects

In GreenCHAINge an innovative “smart chain” is being developed. Overall goal is to improve the intrinsic quality of the product on the shelf.

Objective

Obtain uniform and RTE (Ready to Eat) mangos on the shelf.
 Understand reasons for internal defects like pulp-browning.
 Improve quality by controlling reasons for internal defects.

Results

Measuring the internal defects of > 3000 mangos transported from Brazil to the Netherlands, in 9 shipments between Nov '16 and Jan '17 shows that pulp-browning correlates with:

- Decreased firmness.
- Increased internal dark yellow color.
- Higher ripening temperature.

Additional experiments showed that pulp-browning correlates with increased storage time.

Making 1 cm² mango cubicles to mimic “cut mango pieces” shows that an increase in internal breakdown correlates with browning of the mango cubicles.

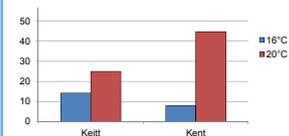
Conclusion

Internal pulp browning is most observed in ripe mangos.

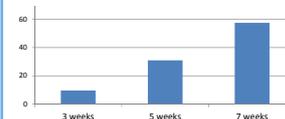
Relevant for industry

A better understanding of the factors that trigger internal defects / browning can help to improve the current logistics chain, minimizing practices that contribute to the problem.

“Nice to see that the common hypothesis “browning correlates with ripening” is verified”



Percentage of internal breakdown increases at higher ripening temperature, for both cultivars Keitt and Kent.



Percentage of internal breakdown increases upon longer storage (respectively 3 weeks, 5 weeks or 7 weeks at 16 °C).

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Pre-Harvest factors effect on post-harvest Mango quality

In GreenCHAINge an innovative “smart chain” is being developed. Overall goal is to improve the intrinsic quality of the product on the shelf.

Objective

Obtain uniform and RTE (Ready to Eat) mangos on the shelf. Obtain an objective and reliable method to phenotype mango quality. Assess the effect of pre-harvest factors on mango quality.

Results

Pre-harvest conditions like rainfall, humidity, temperature, and the use of fertilizers and chemicals were recorded during time and per orchard.

- Variation in mango quality could not be correlated to variation in climate or orchard management since climate only varied slightly while orchard management varied significantly.
- From the 51 monitored variables 16, were identified with a significant variation.

The temperatures between harvest and start of the transport per reefer container differed for each shipment. On some occasions mangos remained warm (>15 °C) for more than 48 hours before being pre-cooled and transported.

Conclusion

Since there is a difference in the usage in 16 pre-harvest treatments it is not possible to pinpoint one particular solution to post-harvest quality. Although no strait forward correlations could be identified, insights in variation and temperature management provide useful information for agronomist and quality control.

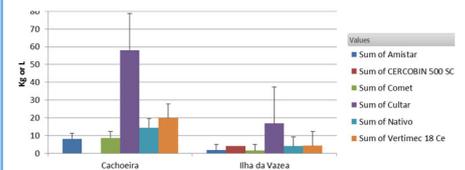
Relevant for industry

Creating reliable and comparable datasets is a prerequisite to find correlations. The feedback of quality on arrival offers the opportunity to find correlations in the near future.

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“Insights in variation and temperature management provide useful information for agronomist and quality control”



Variation in used chemicals per orchard for the same time period in orchard I and orchard II.

For detailed information about this project result please visit www.wur.eu/greenchainge.







Predicting Mango quality via NIR-measurement

Sorting mangos based on desired attributes can be achieved via non-destructive Near-InfraRed (NIR) spectroscopy, where NIR spectra of incoming batches are calibrated using batches with known firmness/BRIX/Dry Matter scores. Currently, due to the large variation in quality and maturity of mangos, a substantial amount of fruits arriving at the wholesaler have internal defects or are misclassified after sorting. Models allowing proper sorting based on non-destructive measurements, would increase the value in the whole mango chain and decrease post-harvest losses. This is the outcome of a research project, by Wageningen Food & Biobased Research, carried out within the GreenCHAINge project.

In GreenCHAINge, an innovative “smart chain” was developed, with the goal of predicting fruit and vegetable quality without causing product damage, and improving on-shelf quality. Work Package 1 focused on quality prediction for mangos using non-destructive Near-Infrared Spectroscopy (NIRS). In industry, mango NIR spectra are measured high throughput, and mangos are sorted using standard linear regression models, with approximately 50% efficacy. We propose to classify mangos using a “learning by comparison” model. Therefore, NIR spectra were correlated with quality traits like firmness, BRIX score and percentage of Dry Matter (DM).

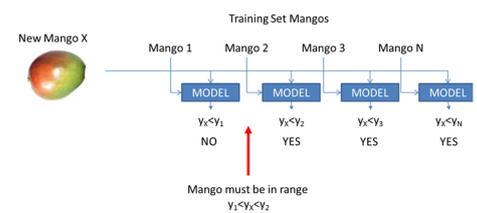
High accuracy

The scientists measured NIR spectra of over 1,500 mangos at different moments in time between harvest (in Brazil), transport to the Netherlands and at several moments during controlled ripening. A “regression by comparison” model enabled them to compare each measurement with existing data. This resulted in the prediction of BRIX scores, DM percentages and firmness with 89%, 84% and 70% accuracy respectively.

Prediction tool

Instead of a regular linear regression model to predict mango quality, we developed a classification system based on a “learning by comparison model”. In industry, a substantial amount of mangos have internal defects or are misclassified. Therefore reliable classification models are crucial to allow effective classification of mangos for ripeness and internal defects. Optimal decision making in the mango supply chain improves uniformity and decreases post-harvest losses. This would finally increase the value in the whole mango chain.

“Classification of mangos based on NIR spectra is possible using a “learning by comparison model”



In a “regression by comparison” model to predict ‘firmness’, each NIR spectrum is compared to NIR data of mangos with known firmness.

For detailed information about this project result please visit www.wur.eu/greenchainge.

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Tracking Mango quality pre-harvest until RTE-stage

In GreenCHAINge an innovative “smart chain” is being developed. Overall goal is to improve the intrinsic quality of the product on the shelf.

Objective

Obtain uniform and RTE (Ready to Eat) mangos on the shelf.
Predict mango quality by measuring pre- and post-harvest traits.
Track 100 Keitt and 100 Kent mangos from 5 weeks pre-harvest till RTE stage, using non-destructive NIR (Near-infrared) measurements to identify key maturity predictors.

Results

Weekly non-destructive NIR measurements using a FELIX-F750 handheld including a model to predict DM (Dry Matter) and BRUX (sugar content) with an R^2 (predictability) of respectively 68% and 57%, on 200 mangos predict that DM and BRUX increase in time.
Firmness data are too inaccurate to predict firmness by NIR.
Pre-harvest NIR spectra from all 100 mangos follow the same change of amplitude in time, indicating we can track maturity.
Capturing NIR spectra in values indicates significant changes in time (weekly from 5 weeks pre-harvest till RTE stage), enabling us to correlate NIR spectra with maturity!
Based on NIR spectra we can predict level of maturity, which correlates to BRUX.

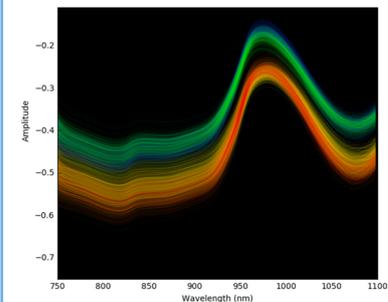
Conclusion

Instead of indirect tracking maturity (via traits like DM, BRUX or firmness), we can directly track maturity by capturing values of NIR spectra!
Holds true when weekly measuring at the same mango spot.

Relevant for industry

Values of non-destructive NIR measurements are a novel marker to directly track maturity. Being able to track maturity while fruit is still on the tree, could help the grower in determining the optimal harvest moment.

“Capturing NIR spectra in a value allows us to directly track maturity!”



NIR spectra (“dark blue/green” 5 weeks pre harvest till “red” (RTE)) correlate with maturity.

For detailed information about this project result please visit www.wur.eu/greenchainge.

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Harvesting Melon: choosing the optimal moment

Melon quality, and in particular the post-harvest quality of new varieties, is met by high demands from the European market, which requires a pristine condition of peel quality and high quality of flavour. Harvesting melons at the right moment is crucial to ensure high-quality, tasty melons with a beautiful peel. Harvesting melons at fully mature stage is most optimal for sweetness and the desired aroma. However, to increase shelf life, melons are harvested already at a partially mature stage. Optimal harvest moment is crucial to obtain high quality and uniform melons on the shelf. This is the conclusion drawn from a research project by Wageningen Food & Biobased Research, carried out within the GreenCHAINge project.

In GreenCHAINge an innovative “smart chain” was developed with the intention of improving the intrinsic quality – and uniformity - of fresh fruit and vegetables on the shelf. In the context of research in Work Package 2, the subject was melons.

Maturity and quality

The scientists measured the quality of melons harvested at 63, 65 and 67 days after transplant (DAT) (days after the melons were transplanted from seedling stage to open ground), and correlated maturity stages to quality characteristics in order to identify the optimal harvest time.

Melons harvested 67 days after transplant showed increased levels of BRIX and brown speckles, compared to melons harvested at 63 and 65 DAT. No increase in weight was observed, assumed to be caused by variations in flowering moment.

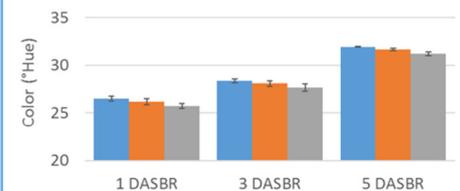
Early versus late flowering

Early-flowering melons, meaning flowering one day after spam bond removal (DASBR) and harvested 65 days after transplant, were heavier, showed higher BRIX levels and a darker peel compared to later flowering melons (3 or 5 DASBR). They also showed more peel disorders, such as brown speckles and gray areas. The peel-colour progression rate was the same for both early and late flowering melons.

Follow up research

The scientists concluded that DAT and DASBR are useful measures to establish optimal harvest time, when combined with post-harvest maturity measurements.

“Measuring maturity at various stages helps optimize harvest time, increasing initial quality as the cornerstone of high quality throughout the chain”



Increase in colour in early-flowering melons (1 DASBR) compared to late-flowering melons (5 DASBR). (Lower colour value indicates greater yellowness).

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Optimizing storage conditions to preserve Melon quality

Storing melons at 7°C causes only minor peel defects, allowing product buffering at the distribution centre, without quality loss. This is the expert conclusion of Wageningen Food & Biobased Research following research under the umbrella of the GreenCHAINge project. Storage at distribution centres will provide fruit and logistics companies increased flexibility when supplying supermarkets with fresh produce.

The four-year program GreenCHAINge, successfully completed on December 2018, aimed to improve the intrinsic quality of fresh fruits and vegetables on the shelf by developing an innovative 'smart chain'. Work Package 2 focused on maintaining high-quality and uniformity in melons for retail sale, and the reduction of post-harvest losses across the supply chain, by defining optimal storage conditions. Storage at suboptimal conditions can cause speckles and/or grey areas on the peel, strongly affecting the perception of quality. This, since the presence of brown speckles and grey areas on the peel is often perceived as bad quality melons by consumers.

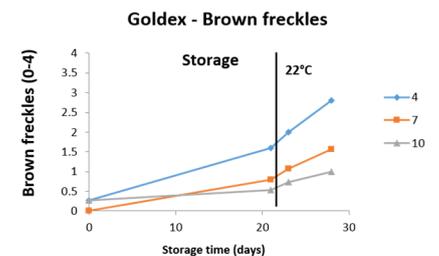
Avoiding speckles and grey markings

The scientists measured the peel quality on melons stored for 20 days at 4°, 7° or 10 °C and found that melons stored at 4°C developed relatively large numbers of speckles. Melons stored at 7°C had for industry acceptable amounts of speckles and grey marks, whereas melons stored at 10°C had large grey areas. Weight loss increased with storage temperature. Taste and BRIX levels, however, remained the same.

Conclusion

Melon quality decreases during a buffer period. Peel disorders like brown freckles and brown spots increase after a buffer period at 4°C. Therefore, buffering at 7°C might still allow induction of ripening at 20-22°C, while keeping the peel disorders to an (acceptable?) minimum.

"Melons with a perfect peel are perceived as high quality. Optimal storage is essential to reduce peel defects and increase retail sales"



The number of speckles increases upon storage at 4°C. At 7°C the number of speckles remains acceptable, also at 22°C (simulating) the retail phase.

For detailed information about this project result please visit www.wur.eu/greenchainge.

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Volatiles-production correlates with ripening stage of Melons

The production of volatiles correlates with the ripening of melons and is affected by time and temperature. This is the conclusion from research by Wageningen Food & Biobased Research, carried out within the GreenCHAINge program. The insights gained allow chain partners to optimize the moment of harvest, the storage and the retailing of melons.

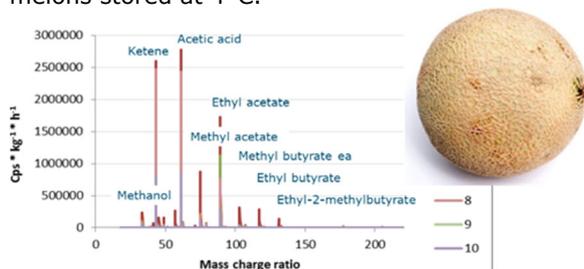
The four-year program GreenCHAINge, successfully completed in December 2018, will improve the intrinsic quality of fresh fruits and vegetables on the shelf, via its innovative 'smart chain'. Work Package 2 focused on delivering and maintaining high-quality and uniform melons in-store.

Ripening and volatiles production

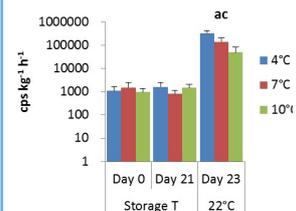
First, the scientists determined the maturity and ripening stages of melons from the popular cultivar Natal, and then defined the optimal moment for harvesting and post-storage sales. They measured volatile profiles at different storage temperatures and correlated ripening stages with the melon's volatiles production. Key volatiles include acetaldehyde, esters and ethanol; fruity odours that relate to fruit ripening.

Volatiles production during storage

Production of volatiles, correlated to ripening, appeared to decrease during storage, irrespective of storage temperature. Melons released more aroma volatiles (acetaldehyde, esters and ethanol) at 22°C (simulating home and supermarket conditions), compared to 4°C (simulating storage). Measuring the volatile profile of melons initially stored at 4°C, 7°C or 10°C, and subsequently stored at 22°C, showed an increase in volatiles production upon the rise in temperature, suggesting an accelerated ripening after cold storage, which was the highest for melons stored at 4°C.



"Correlating the volatiles pattern (aroma) with ripening allows optimal timing of harvest, storage- and point-of-sale time in the chain"



Volatiles production at 0, 21 and 23 days after storage. Melons were stored from day 0 till 21 at 4°C, 7°C or 10°C, followed by warming up to RT (Room Temperature, 22°C) from day 21 onwards. After 21 days of storage and the rise to 22°C, volatiles production increases significantly.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Anti-fungal treatments reduce mould development in Papayas

Packaging papayas prior to transport, and heat treatment upon arrival at the wholesaler, reduces post-harvest fungal infection. Heat treatment prior to transport seems likely to be even more effective against fungal infection. This is the outcome of studies by Wageningen Food & Biobased Research, conducted under the umbrella of the GreenCHAINge program. The work supports the fresh fruit industry in increasing the quality of papayas on the shelves of European stores.

The four-year program GreenCHAINge aimed to improve the intrinsic quality of in-store fresh fruit and vegetables by developing an innovative 'smart chain'. The main focus of Work Package 2 was on ensuring high-quality papayas on retail shelves.

Notorious problem

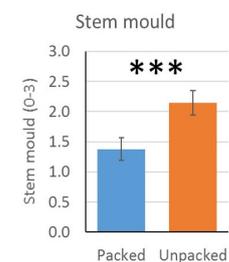
The scientists investigated whether packaging, heat-treatment or controlled atmosphere (CA) could reduce fungal infection, a notorious problem, in the exotic-fruits market, especially since certain fungicides are prohibited.

Prom packaging to heat treatment

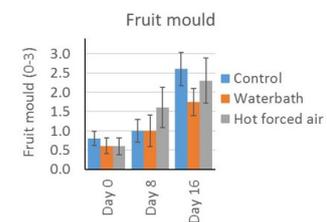
Measuring the hydration status and mould levels of 200 papayas, transported from Brazil to the Netherlands, indicated that packed papayas had a 0.5% higher moisture content, and reduced mould on both stem and fruit compared to unpacked papayas. Papayas stored for 16 days in CA were less dehydrated, but had similar levels of mould, compared to papayas that had not been stored in CA. Heat-treated papayas showed less fruit mould when treated at 49°C for 5 minutes, and less stem mould when treated at 49°C for 30 minutes.

Conclusion

Heat treatment of papayas seems to have potential in reducing the developments of mould. Particularly the application of the water bath, which is already in use to export papayas from Brazil to the US to destroy insects, could be applied "fast/easy" to prevent mould development long distance export (2-3 week transport overseas) to Europe. Transport of papayas overseas, instead of by air transport, while maintaining quality levels, has both economic as well as environmental advantages.



Occurrence of stem mould is reduced when papayas are packed.



Heat treatment of papayas, prior to storage for 8-16 days, reduced the occurrence of stem mould.

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Papaya post-harvest quality factors

The papaya cultivar, Tainung, is the sweetest and is least affected by moulds after transport from Brazil to the Netherlands. Papayas can be harvested either green or at a mature stage, and require an antifungal treatment after washing. This is the key message of a research project by Wageningen Food & Biobased Research, carried out under the umbrella of the GreenCHAINge program. The findings provide fruit companies with new opportunities to optimize product quality.

The four-year program GreenCHAINge, successfully completed in December 2018, aimed to improve the intrinsic quality of fresh fruits and vegetables on the shelf by developing an innovative "smart chain". Work Package 2 focused mainly on ensuring the highest quality of papayas on the shelf, following transport from Brazil to the Netherlands.

Best characteristics

The scientists monitored the quality of three papaya cultivars - Tainung, Bela Nova and Maradona – during transport and simulation of distribution (10°C) and retail phases (22°C). Their aim was to select the papaya cultivar with the best post-harvest traits and determine the optimal harvest stage and post-harvest treatment.

Based on Brix (sweetness) scores and mould levels, Tainung appeared the best cultivar of the three. Retail simulation did not show any quality differences between papayas harvested at a green versus mature stage. However, on the day of arrival at Wageningen the colour and mould levels were lower in papayas harvested at the green stage.

Post-harvest treatment

The combined effects of washing, applying a wax layer and giving an anti-fungal treatment minimized weight loss and mould compared to no treatment, or just washing and applying a wax layer.

Papayas can be harvested at both the green or mature stages but, after washing, both a wax layer and an anti-fungal treatment should be applied, before transport.

"Maturity of papayas is determined based on the so called 'stripes' on the skin of the fruit. The more stripes, the more mature. However, quality of papayas - after 3 weeks transport - does not depend on the maturity stage at harvest"



Phenotyping papaya internal quality.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Papaya taste profile

What is the best way to find papayas that are still tasty after long transportation? Wageningen Food & Biobased Research carried out research on this subject under the auspices of the GreenCHAINge programme. The findings will help fruit companies take well-considered decisions regarding the selection of both cultivars and markets, and increase the market opportunities for papayas in Europe.

Intrinsic quality

The four-year programme GreenCHAINge aimed to improve the intrinsic quality of fresh fruits and vegetables on the shelf by developing an innovative 'smart chain'. The key focus of work package 2 was to ensure high-quality, tasty papayas in shops following transport from Brazil to the Netherlands.

Consumer panel

The scientists asked a panel of consumers to compare the taste of two cultivars in a Tetrad test. Tainung, an established cultivar, was judged to have a taste significantly different from that of the novel papaya cultivar to which it was compared. Tainung had lower scores on bitterness and aftertaste and was perceived to be sweeter. As such, it was preferred to the novel cultivar, which was found to have a taste profile similar to the cultivar Maradona but with a sweeter, nuttier flavour. Overall enjoyment was positively correlated with sweetness and fruitiness, and negatively correlated with bitterness and aftertaste.

Effects of transportation

Papayas destined for the European market usually originate in Brazil, Peru or Mexico. Transportation overseas requires approximately two to three weeks. To prevent softening and damage in transit, papayas are harvested while still unripe, and ripened before delivery to supermarkets. This leads to papayas in Europe generally having a less rich taste than papayas that have ripened on the branch and are freshly consumed. It is therefore crucial to select papaya cultivars with a taste profile that is appreciated by consumers and able to survive the long transport.

"Papayas with increased sweetness and decreased bitterness are key to stimulating Europeans to eat more papaya."



The sensory profiles in this spider chart – where each axis represents a taste attribute – show that Maradona (orange) is similar to the novel cultivar (grey), while Tainung (blue) is quite different.

For detailed information about the results of this project, please visit www.wur.eu/greenchainge.

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Effect of maturity and shelf life on taste perceptions of Strawberries

Maturity at harvest has an essential influence on the taste of strawberries. Taste perception of unripe strawberries does not improve during shelf life and never achieves the test scores of ripe strawberries. This is the main conclusion drawn from Work Package 3 by Wageningen Food & Biobased Research carried out within the GreenCHAINge project. The findings highlight the importance of harvesting strawberries at the optimum, not-too early, stage of ripeness. GreenCHAINge, successfully completed in 2018, established a 'smart chain' that allows fruit businesses to improve the intrinsic quality of on-sale fresh fruit. Research aimed to increase understanding of factors affecting the quality of strawberries in order to optimize taste – perhaps the major contributor to how consumers perceive the quality of this popular soft fruit.

Taste development

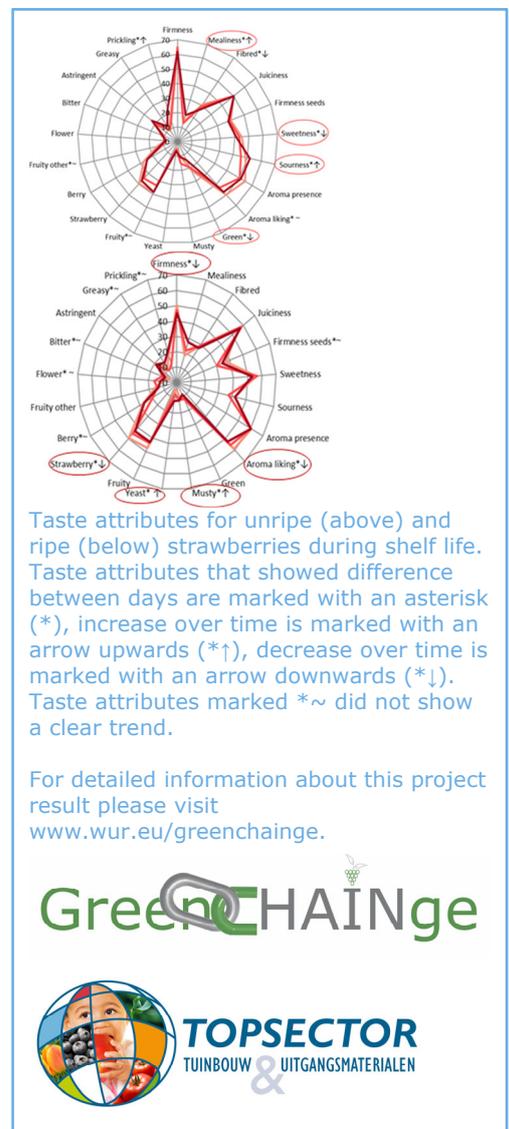
The scientists measured the effect of maturity stages on consumers' taste perception of strawberries. They assessed the development of taste throughout shelf life and identified key sensory attributes in strawberry-taste perception.

From juiciness to prickling

Ripe strawberries scored high on the sensory attributes of juiciness, sweetness, aroma presence, aroma liking, fruity aroma, strawberry aroma. These attributes contribute positively to taste perception. unripe strawberries scored higher for negative aspects such as sourness, green aroma, bitterness and astringency. In addition unripe strawberries showed high score for overall firmness and seed firmness whereas ripe strawberries scored higher for mealiness. For ripe strawberries - during shelf life - the scores for firmness, aroma liking and strawberry aroma decreased. For unripe strawberries, during storage time, sweetness, green aroma and fibred (fibrous mouth feeling), decreased, while mealiness, sourness and prickling increased.

Maturity stage

The effect of maturity stage on taste and flavour is far stronger than the effect of length of storage. Ripe strawberries correlated with the perception of pleasant fruity aromas and sweetness. The changes in flavour and taste perception during shelf life differ significantly between ripe and unripe strawberries. Ripe strawberries lose strawberry aroma and are less appreciated by the consumer. Unripe strawberries are perceived as even less sweet. The score, for pleasant aroma of unripe strawberries, does not increase over storage time.



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Firmness and shelf life of Strawberries

Firmness is a good indicator and predictor of strawberry quality and shelf life throughout the chain. This is the main conclusion drawn from a project by Wageningen Food & Biobased Research carried out within the GreenCHAINge program. The findings offer fruit companies new opportunities to optimize the quality of their products and reduce food waste.

The four-year research program GreenCHAINge, successfully completed in 2018, developed a 'smart chain' that empowers fruit businesses to improve the intrinsic quality of on-sale fresh fruit. In Work Package 3 objective methods were developed that assess and predict the quality of soft fruit. These approaches enable the industry to take well-considered decisions on harvest time, storage and transport.

Immediately after harvest

This particular research project focused on establishing uniformly-high strawberry quality on the supermarket shelf, and quality prediction immediately after harvest. Quality was measured according to a common quality marker *decay-score**, which measures defects and bruising.

It was found that the lower the strawberry firmness, the higher the fruit decay score. The rate at which quality decreased depended on the specific cultivar but was the same throughout the season. Different ripening stages at harvest were also tested. The results showed that the rate at which quality decreased was similar to all ripening stages.

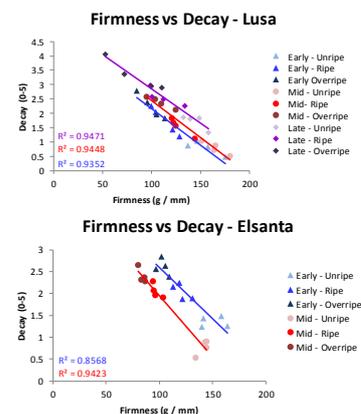
The firmness measurement proved to be applicable to a number of different strawberry cultivars. Bottom line is that firmness is a good indicator of the expected level of decay and may be used as marker to predict strawberry shelf life in the chain.

* *Fruit Decay Score Range: (0 = no bruises/damage, to 5 = severe rot/damage)*

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"Firmness is an excellent indicator of the expected level of decay"



Relationship between firmness and fruit decay score. The upper graph shows the results for the cultivar Lusa and the lower graph for Elsanta.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Non-destructive measurement of Strawberry taste

One of the goals of the GreenCHAINge project is to develop non-destructive methods to measure quality. Taste is an important feature of quality. The current assessment of taste with expert or consumer panels is expensive and time consuming. Therefore alternative methods are needed.

Scientists have explored the potential of volatile detection with PTR-Qi-TOF to assess the taste of strawberries. In addition, the volatile production of ripe and unripe strawberries during shelf life was monitored.

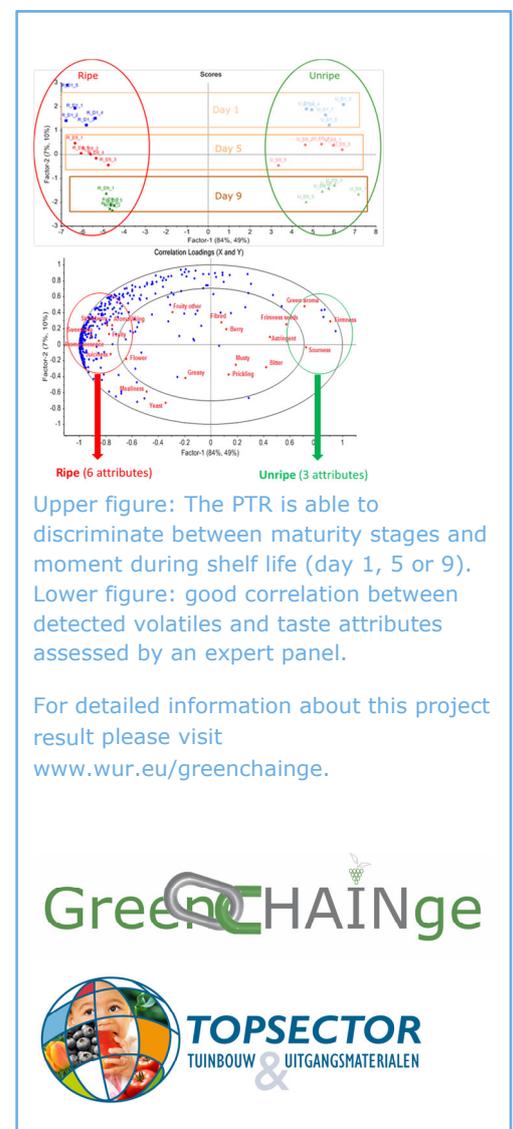
Taste attributes are linked to volatiles

Taste attributes linked to ripe strawberries are well related to several of the measured volatiles. A limited number of volatiles is present in higher concentration in unripe strawberries. These are related to the taste attributes firmness, green aroma and sourness. Mealiness and yeast are particularly correlated to ripe strawberries with longer storage time (day 9).

Non-destructive method for the industry

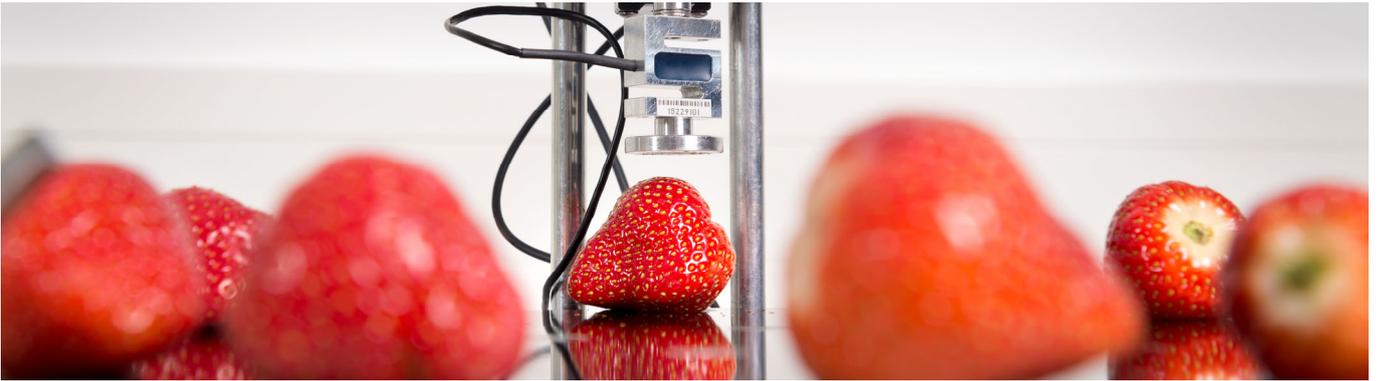
The PTR spectra correlate well with the expert panel. A number of volatiles measured with the PTR are linked to specific taste and flavour attributes measured by the expert panel. This study is a first step into the development of a new objective technique to assess the taste of strawberries.

A non-destructive and fast method to assess taste and flavour is interesting for the industry not only for the screening of new cultivars but also as a tool to monitor and improve the consumer taste perception of strawberries.



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Strawberry firmness and maturity

The more ripe strawberries are when harvested, the softer they are and the shorter their shelf-life. This is one of the key outcomes of a research project, by Wageningen Food & Biobased Research, under the umbrella of the GreenCHAINge program. The findings highlight the importance of well-informed decisions about harvest time and strawberry type.

The GreenCHAINge program developed a 'smart chain' that empowers fruit businesses to improve the intrinsic quality of on-sale fresh fruit. Work Package 3 improved our understanding of how the quality and shelf life of different strawberry cultivars are affected by maturity at harvest.

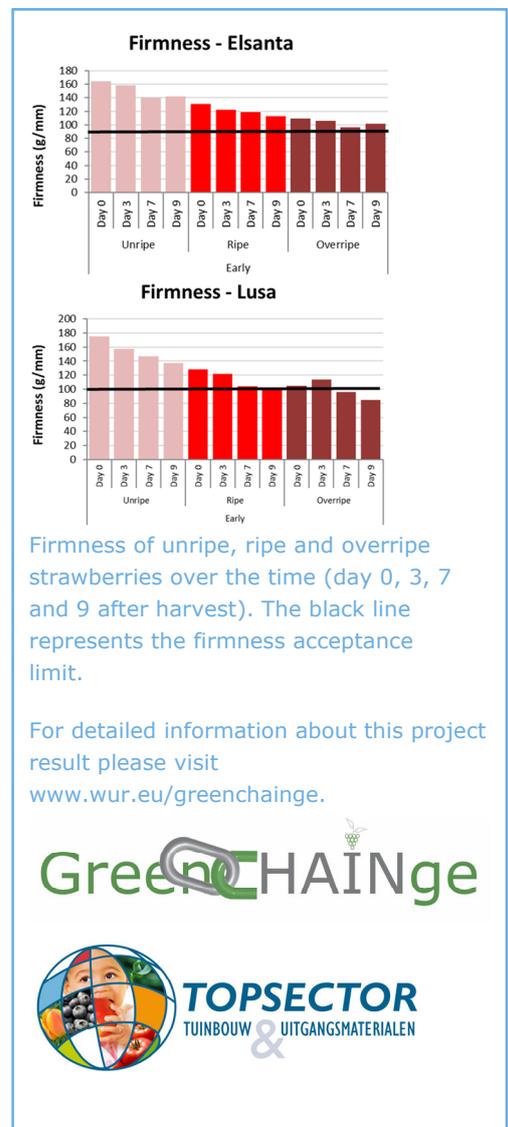
Comparing firmness

Scientists measured the relationship between maturity stage and firmness for different commercially important cultivars, including Lusa and the Elsanta. They also compared the firmness of different batches of strawberries during shelf life and at different moment during the production season.

Season and cultivar effects

Strawberries harvested when ripe were softer than strawberries harvested while not yet ripe. For all strawberries, firmness decreased over time. The rate at which they became soft depended on the cultivar and the production season moment in which they were harvested.

For the soft fruit business this means the quality of strawberries can be managed based on the ripening stage at harvest and a suitable cultivar choice. For example when supplying a distant market, firmer cultivars should be selected and strawberries should be picked in less ripe stage. Companies have the chance to match the consumer requirements to the most suitable ripeness stage of the cultivar throughout the season.



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Methods for measuring Mushroom quality

The whiteness of mushrooms is a valuable indicator of quality and freshness. A camera-based system, however, delivers more accurate and objective data than a human using a colour card. This is one of the conclusions from a research project, by Wageningen Food & Biobased Research, under the umbrella of the GreenCHAINge Program. Using standardized quality measurements will ensure only quality product is offered to the consumer.

The GreenCHAINge project developed an innovative “smart chain”, with the overarching goal of improving the quality of fresh produce on the shelf. Work Package 4 focused on the assessment and prediction of mushroom quality under varying conditions during cultivation (e.g. compost) and across the chain (e.g. temperature). Mushrooms are highly perishable fresh produce, turning brown very quickly.

Two new methods

The scientists developed two new methods to measure the whiteness of mushrooms. A handy colour card displaying different gradations of white, and camera software that can detect even the smallest differences in white colour, as well as brown discoloured areas. Both methods help with quality assessment in research as well as in practice, but the camera system provides objective and more-accurate measurements compared to quick and low-cost assessment using the colour card.



Objective method for measuring whiteness and discolouration by using image analysis.

For detailed information about this project result please visit www.wur.eu/greenchainge.

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Conference Pears: quality prediction and decision-support

A new way of modelling for quality prediction in fresh chains using Bayesian networks is the outcome of a project by Wageningen Food & Biobased Research, carried out within the the GreenCHAINge program. The approach, which can be tailor-made to specific company needs, will support (quality) managers to make the best possible decisions about markets, storage and transport and of Conference pears, across the supply chain.

The goal of the "smartchain", developed by GreenCHAINge, is to improve the quality of fresh fruits in store. Work Package 5 focussed on the export of pears to (new) distant destinations.

Bayesian-network model

The scientists were the first to develop a Bayesian-network model to predict the quality of a batch of pears, combining various data sources. The model uses data from practice, input from experts and experimental outcomes. It integrates multiple conditions and relations between factors involved in quality. This is significantly more than the human brain, which, cannot effectively handle more than a few related activities at once.

Prediction of firmness

The model currently focusses on predicting the chances of successfully ensuring the desired firmness for a batch of Conference pears at a specific time in its journey through the chain. Model input data are, for example origin, harvest time, storage and transport conditions, and SmartFresh treatment. The model also provides added insight via a sensitivity analysis: which supply-chain factors contribute most to each quality parameter and should, therefore, be prioritised in quality management?

"Adapting the model to company-specific needs and linking it to data-management systems maximizes the advantages of the model in practice"

For detailed information about this project result please visit www.wur.eu/greenchainge.

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Modified Atmosphere Packaging (MAP) improves shelf life of Pears

Significantly larger market opportunities is just one benefit of research showing that MAP contributes to better post-harvest quality of pears. Conducted by Wageningen Food & Biobased Research as part of the GreenCHAINge program, the outcomes show that firmness of pears can be maintained better throughout the chain.

MAP in the destination country

The GreenCHAINge project's overall goal is to improve the quality of fresh product on the shelf. Set to become a key part of the 'smart' chain, Modified Atmosphere Packaging helps extend the shelf life of fresh produce. Its efficacy is dependent on foil type, pear respiration and temperature conditions in the chain. For Conference pears the target atmospheric oxygen percentage is 1-3%, as this reduces respiration: CO₂ concentrations must be under 5% to prevent risk undesirable physiological changes.

Firm, fresh-looking pears at point of sale

The scientists packed batches of pears in different films, in simulated chain conditions, including distribution (5 days 8°C)/retail phase (5 days 18°C). In packages using a new type of film, an effective modified atmosphere was achieved, whilst those using regular film (BOPP with micro-perforation) resulted in damaging CO₂ levels. Firmness and appearance were better for pears in the new MA packaging, compared with normal air conditions.

Reliable application

Results show that correct application of MAP increases the shelf life of pears. It helps to maintain desired product characteristics throughout chains, even those serving distant markets.

"Optimized MAP significantly improves shelf life of Conference pears"



Packaging materials for packing fresh produce.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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SmartFresh: effects on volatile production and taste of Pears

SmartFresh technology is increasingly used commercially on pears to help delay ripening. The effects of this emerging technology on pears' volatiles production are negligible in terms of customer taste experience. These are some of the outcomes of a research project, by Wageningen Food & Biobased Research, under the umbrella of the GreenCHAINge project. The findings highlight the added value of SmartFresh to extend shelf life and to facilitate increased export distances.

GreenCHAINge aims to develop a 'smart chain' that allows fruit businesses to improve the intrinsic quality of on-sale fresh fruit. Work Package 5 of the project focuses on the export of pears to distant destinations, exploring how SmartFresh's 'anti ripening' technology (1-MCP) could extend shelf life and improve post-harvest quality of, in this case, pears.

Conference pears

Scientists conducted a number of experiments to understand how SmartFresh technology affects volatile (aroma) production in pears. Blind taste trials, with an untrained consumer panel, were also used. The researchers chose Conference pears, as this is the most-cultivated variety in the Netherlands.

No taste difference

Pears treated with SmartFresh produced lower amounts of aroma volatiles (esters and alcohols). Amounts produced were measured non-destructively (using PTR-TOF-MS) on treated and untreated pears of comparable firmness. Between the two groups, taste panels found no difference in aroma or taste.

SmartFresh technology:

- Increases export distance
- Extends pear shelf-life
- Improves post-harvest quality

while having negligible effects on taste of pears.

For detailed information about this project result please visit www.wur.eu/greenchainge.

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SmartFresh technology extends shelf-life, even when applied after storage

Using SmartFresh to extend the shelf-life of pears could be a valuable approach in fruit export, increasing customer satisfaction and bringing new markets within reach. This is the conclusion from a research project, by Wageningen Food & Biobased Research, under the umbrella of the GreenCHAINge project.

The GreenCHAINge project developed an innovative “smart chain”, with the overarching goal of improving the intrinsic quality of the product on the shelf. Work Package 5 focused on the export of pears to distant destinations, such as China. New insights continue to arise into the application of SmartFresh (1-MCP) technology, contributing to better post-harvest quality of products intended for distant destinations.

Both storage and transport

The scientists observed in experiments pears can be treated after an initial storage period, during a cold transport, instead of standard protocol after harvest, and still benefit from longer shelf life (firmness of pears). For this SmartFresh treatment during transport to be effective, a higher than usual dosage is needed. The duration of the storage period before treatment and transport appeared to affect treatment efficacy. The efficacy also varied per harvest season, as was also seen with pears treated following protocol after harvest.

Tailored approach

The results highlight the importance of tailoring the treatment protocol to the pear physiology and the circumstances. Insight into the maturity of stored pears, for instance via non-destructive ethylene measurements (PTR-TOF-MS), could provide guidance here.

“Storage period and dosage are crucial for successful application of SmartFresh after storage, to extend shelf life of Conference pears”

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Effects of temperature on Avocado ripening

High storage temperature triggers softening process in unripe avocado

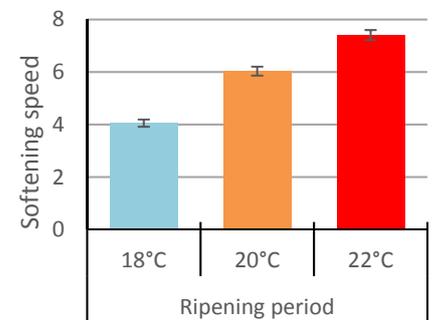
Tropical fruit is harvested before it is ripe in order to allow long-distance transport from the production areas to consumers in Europe. This ensures that it becomes ready to eat (RTE) after arrival.

As part of the GreenCHAINge project, Wageningen University & Research investigated the effects of temperature on the ripening process of avocados. When avocados ripen, they rapidly become less firm. Increasing their temperature from 5-7°C during transport to 16°C upon arrival was found to be sufficient to trigger ripening, with higher temperatures speeding up the softening process. A high storage temperature – above 24°C for instance – was, however, found to lead to a deterioration in quality, such as vascular and pulp discoloration. The daily loss of firmness (softening speed) of avocados at different ripening temperatures over four days is summarised in the figure to the right.

Keeping ripe avocados at low temperature extends shelf life

Cooling down avocados also slows down the continued softening process after they are ripe. Reducing the temperature just after the ripening protocol is applied and during distribution to retail outlets permits the softening rate to be slowed down again, extending the shelf life of RTE avocados.

The effect of low storage temperature at an outlet display was also studied. The shelf life of RTE avocados was extended by three to six days when these were stored at 8°C instead of 18°C (see table). Shelf-life performance is given in relation to the RTE percentage in a batch of avocados. More RTE avocados in a batch translates into a lower shelf-life performance for that batch. Storing RTE avocado at outlet displays at a lower temperature also limited other defects such as dehydration and vascular and pulp browning.



Softening speed of avocados during four days of ripening.

Percentage of RTE avocados in batch	Shelf life at 8 °C (days)	Shelf life at 18 °C (days)
60%	15	9
70%	10	7
80%	10	5
85%	7	3

Lower storage temperature at outlets extends the shelf life of RTE avocados.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Ready-to-eat (RTE) Avocados

The last decade has seen a tremendous increase in the variety of foods consumed. Tropical fruit such as avocado, mango and papaya has become especially popular, despite the unpredictability of ripeness at purchase. To respond to consumer preferences for ripe and tasty fruit, importers of tropical fruit developed a concept called 'ready to eat' (RTE). To achieve RTE status before delivery to supermarkets, fruit is kept in special ripening rooms until it is close to the desired quality. Once ripe, fruit has a limited shelf life and quickly becomes soft and overripe. To ensure that fruit delivered to supermarkets is RTE but still has an acceptable shelf life, it is important to accurately determine its ripeness.

The question asked by the GreenCHAINge WP was: How can we objectively determine the ripeness of avocado fruit?

Ripeness classes

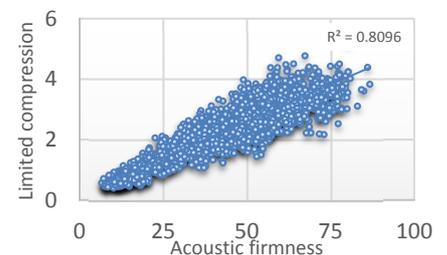
Ripening protocols for avocado were developed within work package 6 of the GreenCHAINge project. To evaluate these protocols, Wageningen University and Research defined a ripeness scale based on fruit firmness. The scale consists of five classes ranging from class 1 (ripened but still too unripe to eat) to class 5 (clearly overripe). A class 1 avocado is too firm and lacks the characteristic avocado flavour, while a class 5 avocado displays pulp discoloration and has a typical overripe off-taste. Avocados in classes 2 to 4 are deemed to be RTE, with class 2 during delivery to supermarkets just right to ensure perfect quality for consumers and minimal waste.

Measuring firmness to determine ripeness

Measuring the firmness of fruit is the most reliable way to assign a ripeness score. Firmness can be measured with great precision using a penetrometer, but this makes a fruit unsellable. Two non-destructive methods, the acoustic firmness measurement and the limited compression method, were therefore employed in combination instead.

Ripeness class	Description	Acoustic [$\text{Hz}^2\text{g}^{2/3}\text{d}^{-1}$]	LC (kg)
1	Not RTE, too hard	> 22	> 1.3
2	RTE, slightly too hard	18.3 - 22	0.93 - 1.3
3	RTE, perfect	11.3 - 18.3	0.66 - 0.93
4	RTE, slightly too soft	9 - 11.3	0.53 - 0.66
5	Not RTE, too soft	< 9	< 0.53

Ripeness classes correlated with degrees of firmness established by acoustic and limited-compression methods.



Correlation between acoustic-firmness and limited-compression measurements.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Ripening homogeneity of Avocados remains a challenge

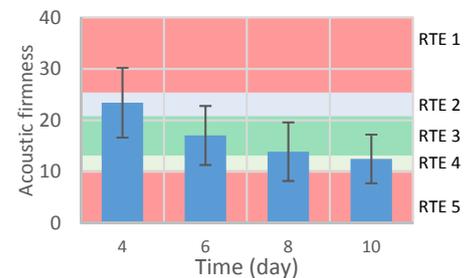
Avocados are an important tropical fruit in Europe. Companies that ripen avocados have introduced the ready-to-eat (RTE) concept to ensure that consumers get the highest possible quality. Within the GreenCHAINge project, Wageningen University and Research has investigated ways to achieve more homogeneous ripening of commercial batches of fruit.

Ripening protocols often consist of storing unripe fruits at high temperature for several days with simultaneous application of ethylene to trigger and synchronise the ripening process. Despite these ripening protocols, not all avocados within a commercial batch reach the RTE stage at the same time. This phenomenon, called ripening heterogeneity, is a major issue for ripening companies and retail outlets as it makes it impossible to guarantee that all fruits in a batch are at the RTE stage. Firmness, which determines the texture and juiciness of the fruit, is an important indicator of ripening stage.

Ripening heterogeneity occurs at different levels in chain

While the moment of harvest for avocados is determined based on dry matter content, a large variability in fruit firmness is already apparent at harvest. This firmness heterogeneity remains both during the ripening period and afterwards in supermarkets. The firmness bandwidths for each ripeness stage are quite narrow (see figure). This means that, although the average firmness of fruit in a batch corresponds to the ripeness stage, the batch also contains unripe and overripe fruit. Decreasing heterogeneity necessitates frequent sorting based on firmness.

Several ways to reduce ripening heterogeneity have been investigated in the GreenCHAINge project. Sorting avocados before ripening on the basis of their initial firmness values was not found to reduce the firmness heterogeneity of a given batch. Pre-ripening heat treatments were also ineffective. Applying ethylene during ripening protocol slightly reduced the ripening heterogeneity but may have also slightly shortened the shelf life of RTE avocados. Sorting avocados after ripening remains nowadays the best option to reduce the firmness heterogeneity of the batch.



Firmness heterogeneity over time and bandwidth of ripeness classes. Only fruit in ripeness classes 2, 3 and 4 are considered RTE.



Colour heterogeneity on the first day following ripening.

For detailed information about this project result please visit www.wur.eu/greenchainge.





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Ripening Plums using the temperature sum

Plums are often grown far from the places where they are consumed. They can, for instance, be harvested unripe in a South African orchard and transported overseas for two to three weeks in a refrigerated container. Upon arrival in Europe, they are ripened to stimulate softening and decrease acidity. Plums have a short harvesting window of four weeks at most, which makes export and continuity in the production period a serious challenge. Moreover, not all plums are suitable for long transportation at low temperatures.

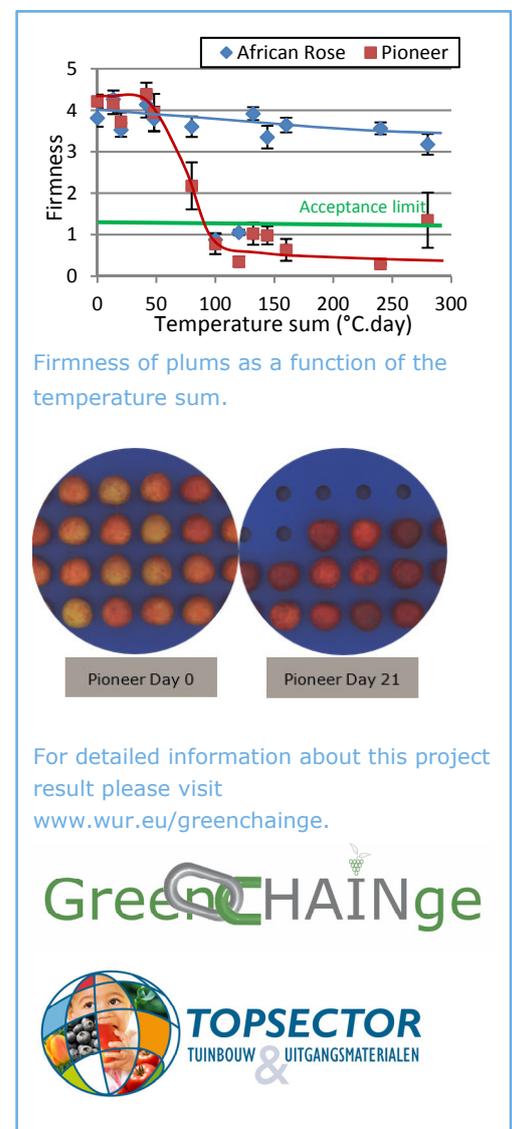
For all these reasons, the export of this fruit is known to be difficult and quality often fails to satisfy consumers. When unsuitable plum varieties are used or transportation conditions are sub-optimal, plums may not properly ripen at the destination and consumers end up disappointed with the quality.

Plum softening dependent on temperature sum

Within the GreenCHAINge project, Wageningen University and Research investigated the behaviour of four plum varieties during ripening and their shelf life. Two of the four varieties (Sungold and Pioneer) were found to ripen well after transport. A clear relationship was observed between the amount of energy applied in the form of the temperature sum during the ripening treatment and the loss of firmness. This means that any combination of temperature and time that results in approximately 100 degree-days will yield softened (edible) plums for these varieties (see figure). This knowledge can be used to optimise the ripening protocols for plums.

Chilling challenges

This behaviour was not observed for every type of plum, however. Two of the varieties examined (African Rose and Southern Belle) did not soften nor reach acceptable quality during ripening. The reasons for this are unclear. The chilling temperatures applied during transport or harvesting at too early a stage may be involved in texture issues (failure to soften or development of a mealy texture) as well as problems associated with taste development such as suboptimal sugar/acidity ratio. Special attention should be given to sensitivity to chilling and maturity index at harvest to optimise the export of these plum varieties.



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Kiwi: NIR measured on skin or flesh

In GreenCHAINge fruit & vegetables, non-destructive measurement techniques are explored and developed. The general aim is to measure quality aspects non-destructively, objectively, repeatable and reliably.

Objective

Compare if Near Infrared (NIR) measurements are influenced by the measurement surface (on the skin or on the flesh).

Test if NIR measurements are able to predict fruit pulp firmness.

Results

>350 kiwis (stored at 20°C) were measured using a SCIO portable NIR (reflectance mode) spectrometer. Each kiwi was measured with and without skin. Penetrometer firmness and brix measurements were taken as reference (ground truth).

- The prediction (R^2) of the Brix and Firmness was improved by removal of the skin.

R^2	Flesh	Skin
Brix	0.745 ± 0.036	0.564 ± 0.055
Firmness	0.553 ± 0.054	0.440 ± 0.053

Conclusion

The SCIO portable NIR can better predict firmness and brix based on measurements on the flesh than measurements on the skin.

Relevant for industry

NIR reflectance measurement on fruit skin is a non-destructive measure, but may yield lower performance when used to predict quality parameters.

"The skin of kiwi suppresses reliable non-destructive measurements of internal quality characteristics like Brix and firmness"

For detailed information about this project result please visit www.wur.eu/greenchainge.

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Mangos: NIR measured on skin

In GreenCHAINge fruit & vegetables, non-destructive measurement techniques are explored and developed. The general aim is to measure quality aspects non-destructively, objectively, repeatable and reliably.

Objective

Predict mango firmness non-destructively using a SCIO portable Near Infrared (NIR) spectrometer.

Results

Three batches of 50 mangos were monitored for three weeks. For each mango NIR and firmness measurements were taken at three or five points in time during these three weeks totaling into 5200 measurements. Partial least squares regression models were employed to perform predictions. Two experiments were performed:

- A R^2 of 0.81 was found using a single batch in dividing the data in a 60%/40% training/test split.
- A R^2 of 0.76 overall was found when each batch was employed in turn as a test set. The resulting individual R^2 values for batches 1, 2 and 3 were 0.74, 0.86 and 0.58 respectively.

Conclusion

NIR measurements on mango skin using the SCIO device appear promising in terms of R^2 as a means of non-destructive firmness estimation.

Relevant for industry

Non-destructive objective phenotyping allows the industry to assess individual mangos during their ripening process.

"The ripening process of mangos can be supported by using inexpensive NIR spectrometers for measuring fruit firmness"

For detailed information about this project result please visit www.wur.eu/greenchainge.

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Pears: NIR measured on skin or flesh

In GreenCHAINge fruit & vegetables, non-destructive measurement techniques are explored and developed. The general aim is to measure quality aspects non-destructively, objectively, repeatable and reliably.

Objective

Compare if Near Infrared (NIR) measurements are influenced by the measurement surface (on the skin or on the flesh).

Compare performance on the task of "exact" prediction (regression) with classifying as firm or soft.

Results

150 Pears divided into 3 batches were tracked over approximately 7 days per batch. Pears were measured using a SCIO portable NIR spectrometer, both on the skin and directly on the flesh itself. Destructive penetrometer firmness measurements were taken as reference values. A model was made to predict firmness levels.

- The model performance was substantially better on flesh ($R^2 = 0.695$) than on skin ($R^2 = 0.430$). Regression using skin measurement is likely too inaccurate for application (currently).
- However, it was noted that the model has potential as a classifier between the classes "soft" and "firm". On flesh, 84.7% of classifications are correct, while on skin this reduces to 74.0%.

Conclusion

Firmness predictions based on flesh measurements substantially outperform those from skin measurements. The SCIO has potential for non-destructive classification of pears into firm/soft classes.

"Measuring pear firmness requires removal of the skin, however for classification in 'soft' and 'firm' you don't have to peel the pears"

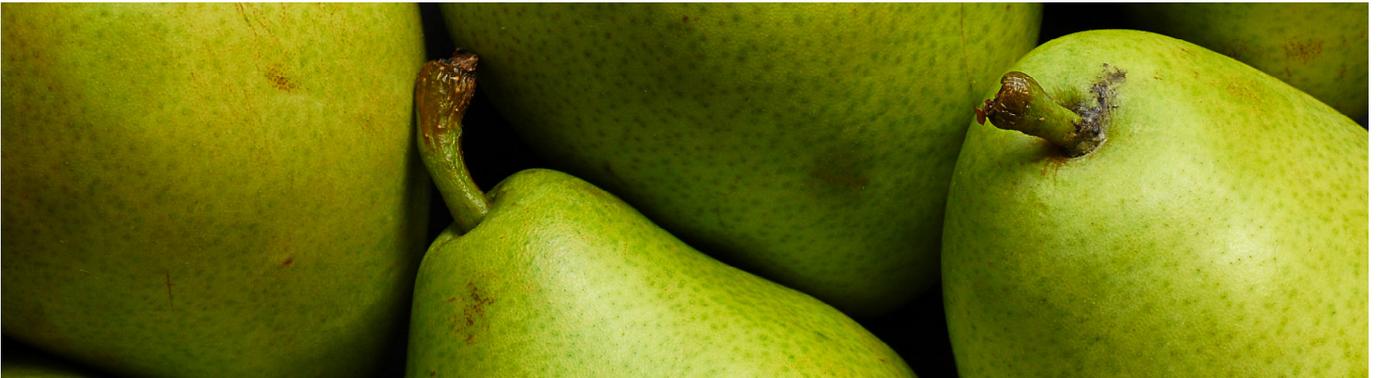
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Pears: Portable versus benchtop NIR spectrometers

In GreenCHAINge fruit & vegetables, non-destructive measurement techniques are explored and developed. The general aim is to measure quality aspects non-destructively, objectively, repeatable and reliably.

Objective

Determine how Near Infrared (NIR) measurements performed by the SCIO portable NIR spectrometer compare with measurements taken with a laboratory Zeiss benchtop spectrometer when classifying pear firmness.

Results

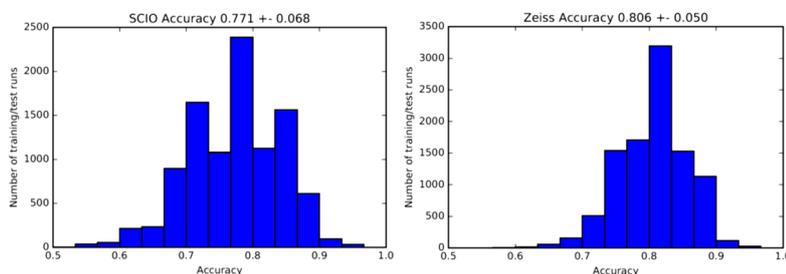
Two batches of 20 pears were measured, one batch with mostly soft pears and one mostly firm pears. Penetrometer firmness measurements were taken as reference.

- The Zeiss spectrometer slightly outperforms the SCIO in terms of mean classification accuracy, but this difference is smaller than the standard deviation of the accuracy means.

Conclusion

The SCIO is promising as an inexpensive and portable alternative to benchtop spectrometer setups such as the Zeiss.

Limitations: Note that differences in measurement protocol, data preprocessing and statistical modelling could alter the performance of either spectrometer. These results should be seen as a guide for further investigation.



Randomized cross validation accuracy results for the task of classifying pears as "soft" or "firm" (left) SCIO results (right) Zeiss results.

"Relatively simple devices such as the SCIO portable NIR spectrometer can achieve comparable results on certain tasks"

For detailed information about this project result please visit www.wur.eu/greenchange.

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