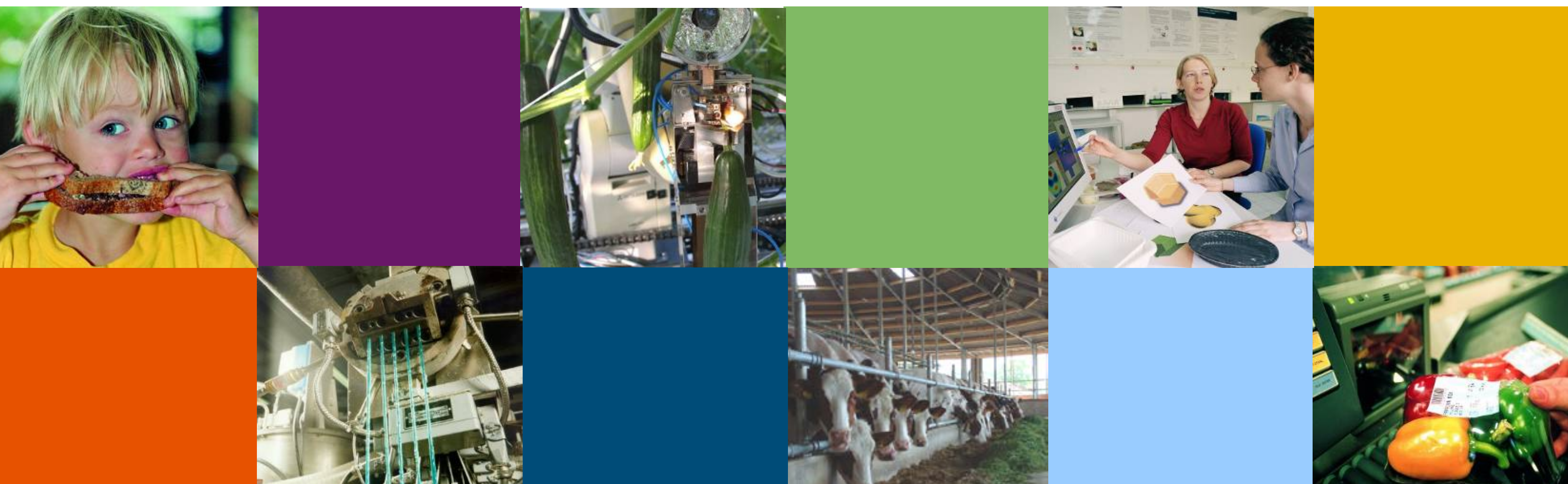
Measuring and Predicting Mango Quality, from harvest in Brazil till RTE stage in the Netherlands

GreenCHAINge WP1 – Mango

Suzan Gabriëls
Eelke Westra

Rapport 1737



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Wageningen Food & Biobased Research
P.O. Box 17
NL-6700 AA Wageningen
Tel: +31 (0)317 480 084
E-mail: info.fbr@wur.nl
Internet: www.wur.nl/foodandbiobased-research

Abstract

The general objective in GreenCHAINge Work package 1, is to develop a more generic quality control system for the AH supply chain that will improve the assurances for consistent quality. One of the subprojects is the study of mangoes, being one of the exotic products delivered to Albert Heijn and serving as a model for other exotic products with the AH fresh food logistics. Mangoes produced in Brazil are transported in reefer containers to the Netherlands. To obtain uniform and RTE (Ready to Eat) mangoes on the shelf in supermarkets, it is essential to:

- Harvest mangoes at an optimal maturity stage
- Transport mangoes at optimal conditions
- Ripe mangoes at optimal temperature and time
- Deliver uniform and RTE mangoes at the right moment

The aim of this study is to predict mango quality based on several destructive and non-destructive measurements. This will enable Albert Heijn, Bakker Barendrecht, MAERSK LINE and VEZET to define optimal harvest, transport and ripening conditions, and to select the best raw material for the processing of cut fruit salads.

The results of this study are promising:

- Measuring firmness at different moments in the mango supply chain enabled us to develop a model to predict firmness in a future stage
- Quality measurements over time allow prediction of RTE stage to a certain extent
- Quality characteristics like internal color and internal defects are measured using "classical subjective phenotyping" as well as using "novel objective phenotyping" methods. Measuring in an objective way reduces variation due to human error and allows standardization of measurements in a continuous scale, throughout the whole world wide supply chain
- Non-destructive measurements of firmness and NIR (Near-infrared) spectra correlate to quality, the capture of NIR spectra in a value might enable the use of each NIR spectrum as a marker to track maturity
- Volatile esters may be used as non-destructive biomarkers to detect ripe mangoes
- Quality measurements over time allow acquirement of suitable raw material for making cut fruit salads
- Precooling has a positive effect on quality of mangoes, while transport to the harbour with or without genset has no significant effect

Accurate prediction of quality allows sorting of mangoes during the chain to finally deliver uniform and RTE mangoes to the supermarkets. To allow proper sorting of mangoes, further optimization of predictive models is required.

Content

1 Introduction

The spearhead of the supply chain for Albert Hein supermarkets (all players) is to achieve a higher return per unit of fresh food shelf space. The performance of the AH fresh food shelves can be improved by the further integration of chain information about quality. Although the processes of individual links in the chain have been optimised to a high degree, this does not provide sufficient assurances for consistent quality. This is due to the nature of the product (biological variation: variety, origins and season) and to the effects of fluctuations in the logistics, packaging, cooling regimes, etc., on the shelf life. The delivery of a more consistent quality would contribute to the required improvement in return (less disappointment, more frequent purchases and lower chain management costs [claims]). The general objective in GreenCHAINge Work package 1, is to develop a more generic quality control system for the AH supply chain that will improve the assurances for consistent quality. This will in turn increase the return per unit of shelf space.

One of the subprojects in GreenCHAINge work package 1 is the study of mangoes, being one of the exotic products delivered to AH and serving as a model for other exotic products with the AH fresh food logistics. Mangoes produced in Brazil are transported in reefer containers to the Netherlands. To obtain uniform and RTE (Ready to Eat) mangoes on the shelf in supermarkets, it is essential to:

- Harvest mangoes at an optimal maturity stage
- Transport mangoes at optimal conditions
- Ripe mangoes at optimal temperature and time
- Deliver uniform and RTE mangoes at the right moment

Delivering uniform and RTE mangoes depends on the quality of the mangoes. In report 1663 (Westra et al., 2016) the brown coloration of cut mango fruits was studied for mangoes harvested in a brown-insensitive period (March 2016) and a –sensitive period (April 2016). Both brown discoloration, as well as the acoustic firmness, correlated with the internal maturity stage. Balancing between a certain maturity while minimizing issues with respect to brown discoloration remains a challenge. In this study we measure firmness, DM (Dry Matter), BRIX (sugar content), internal color and internal browning as traits related to quality. To determine mango quality the Firmness, DM and Brix of mangoes was measured at different time points between harvest at Brazil, transport to the Netherlands and ripening. In addition, non-destructive NIR (Near-infrared) measurements were done and correlated to either firmness/DM/BRIX or maturity levels.

Proper prediction of quality would allow sorting of mangoes in the chain to finally deliver uniform and RTE mangoes to the supermarkets. To allow proper sorting further optimization of the predictive model is required.

1.1 Goal

The aim of this study is to predict mango quality based on several destructive and non-destructive measurements, allowing our clients to define optimal harvest, transport and ripening conditions. This also allows selection of the best raw material for the processing of cut fruit salads.

1.2 Research questions

The results of this study will give an answer to the following questions:

- Can we predict mango firmness at RTE stage based on firmness at the moment of harvest, or at the moment of arrival?
- Can we predict mango quality based on DM/BRIX/internal color/internal browning at a certain moment in the mango supply chain?
- What pre-harvest factors contribute to possible differences found in postharvest quality?
- Do non-destructive NIR measurements correlate to quality traits like firmness/DM/BRIX/internal browning or maturity?
- Can we understand the reasons for internal defects/pulp browning, and can we improve the current logistic chain to minimize practices that contribute to internal defects/ pulp browning?
- Is mango quality different when mangoes are fast-precooled versus slow-precooled before transport?
- Is mango quality different when mangoes are transported to port with or without a generator set (genset) on the reefer container?

2 Methods

Mangoes (cv Keitt and cv Kent) harvested at different orchards (table 2.1) of one grower (AGRODAN) in the Petrolina area in Brazil arrived at Wageningen Food and Biobased Research (WFBR), in nine different shipments between November 2016 and January 2017 (table 2.2).
Per shipment all mangoes were numbered and measured for firmness, weight and NIR spectra upon harvest in Brazil. All mangoes were transported from the orchard to the port of Pecem in Brazil by a reefer container with or without genset. Subsequently, transport continued oversees at controlled temperature of approximately 10 °C. All nine shipments arrived on a Monday at Bakker Barendrecht and were transported to WFBR on Tuesday morning, this to allow quality measurements on a Tuesday ("day of arrival", also called day 0).

2.1 Experiment A: Predict Mango Quality

For experiment "A" mangoes were divided in two groups:
A test group on which the following measurements were done:

- Day 0 (day of arrival): Non-destructive quality measurements of firmness using an acoustic firmness sensor (Aweta) and measurements of NIR-spectra using the FELIX-F750 handheld as near infrared spectrophotometer, followed by ripening for three days at 16°C (24 mangoes per orchard) or 20°C (24 mangoes per orchard).
- Day 3 after arrival: Non-destructive measurements of firmness and NIR spectra, followed by destructive measurements of internal color (class 1 (white/light yellow) till class 5 (dark yellow/orange) (figure 2.3)) and internal breakdown (as % of cut surface)) on mango halves. For 13 mangoes per orchard cubicles of 1 cm^3 were made using a "French fries cutting machine", to mimic mango pieces in cut fruit salads. Subsequently, the half mangoes and the mango cubicles were stored at 6°C (figure 2.3). For shipment one, storage was accidently at 3°C instead of 6°C. NIR spectra were measured for shipment five till nine.
- Day 10 after arrival: Measuring internal color and internal breakdown of the cut mangoes.

A control group of 24 mangoes per orchard (to measure the effect of "just" cutting on internal breakdown and to exclude the ripening effect on internal breakdown) on which the following measurements were done:

- Day 0 (day of arrival): Non-destructive measurements of firmness and NIR spectra, followed by destructive measurements of internal color, and internal breakdown on mango halves. For 13 mangoes per orchard 1 cm^3 cubicles were made and BRIX (using the Hanna-H1 96801 refractometer) and DM (dry weight of four pieces of approximately 0.5 cm^3, kept for 3 days at 80°C, as % of the fresh weight) were measured. Subsequently the mango halves and the 1 cm^3 cubicles were stored for 7 days at 6°C. NIR spectra were measured for shipment five till nine.
- Day 7 after arrival: Measuring internal color and internal breakdown of cut mangoes.

In addition, 96 mangoes from shipment 9 were stored for up till 7 weeks at 16°C or 20°C to allow additional measurements on internal color and internal breakdown.

For pictures of destructive and non-destructive measurements see figures 2.1 till 2.4.

2.2 Experiment 9 AB: Tracking Quality in Time

In shipment 9 an additional set of 100 Kent mangoes and 100 Keitt mangoes was tracked from five weeks pre-harvest (the 100 mangoes were divided over 10 trees, measuring 10 mangoes per tree) till RTE stage, using NIR measurements, followed by additional quality measurements at day of arrival, day 3 (after 3 days of ripening at 16°C or 20°C) and day 10 (after a subsequent week of storage at 6°C).

2.3 Experiment 9 AD: Defected versus Healthy Mangoes

For experiment 9D a set of Kent Mangoes was divided in approximately 100 defected ("collapso" (with internal damage)) mangoes and 100 healthy mangoes to measure NIR spectra in Brazil.

2.4 Experiment B: Transport with fast/slow Precooling and with/without Genset

In shipment 1, 258 mangoes of the cultivar Keitt were transported to the Netherlands with the following variables: 1) with slow or with fast (6 hours) precooling prior to transport, and 2) in a reefer container with or without genset while transported to the port of Pecem (Brazil). Transport from the port of Pecem to the Netherlands was on a container ship, with power connection to the reefer container, and at controlled temperature of approximately 10°C. In shipment 5, a similar set up was followed for 150 mangoes of the cultivar Keitt, to repeat the experiment "with or without genset". The quality of all mangoes was evaluated upon arrival at WFBR, by measuring the acoustic firmness (Aweta). The data was analysed by ANOVA ($p=0.05$) using Genstat 18^{th} edition (version 18.1.0.17005) by VSNI.

2.5 Objective Phenotyping of Internal Color and Internal Breakdown

Objective phenotyping was done using a light and color-standardized cabinet. Mangoes were cut alongside both sides of the seed and the half showing the most internal breakdown was photographed using a digital camera, mounted in the light cabinet. The color-standardized pictures were analysed for color in a two-step approach. First, using color-learning software, colors were associated to either healthy mango tissue or internal defects. Second, using color analysis software, the average Hue value of the healthy tissue and the percentage of the defected tissue were determined.

2.6 Volatile Measurements using PTR-ToF-MS

Volatile organic compound (VOC) production was determined by placing individual mangoes in plastic drums with a septum mounted in the lids and flushing them with medical air at 6 bar for 90 s prior to closure. Subsequently, drums were, after 2 h of headspace accumulation, sampled using PTR-ToF-MS. The PTR-ToF-MS 8000 instrument (Ionicon Analytik GmbH, Innsbruck, Austria) had a drift voltage of 1000V at 60°C and 3.8 mbar, resulting in an E/N of 133 Td. Sampling flow rate was 60 mL/min and the mass range was 20 – 512 m/z. Samples were taken from the drums by direct injection into the PTR-ToF-MS drift tube through a heated (110 °C) peek inlet connected to a syringe needle.
PTR-MS-ToF data was analysed using the program PTRwid (Holzinger, 2015) and subsequently normalized for accumulation time, drum background and mango weight. Multivariate analysis to correlate the volatile and physiological data was performed using Unscrambler X 10.3 (CAMO Software AS, Oslo, Norway). Tentative identification of masses correlating with either ripening time or browning was done using composing an isotopic mass library specifically for mango volatiles, based on Pino et al (2005).

2.7 Analysis of NIR spectra

Analysis of NIR spectra was done using several models. To correlate NIR spectra to BRIX/DM/Firmness, a neural network within a regression by comparison model was used. To follow the evolution of the NIR spectra in time and to track maturity, a linear PLSR (Partial Least Square Regression) model was used. For the classification of defected versus healthy mangoes a neural network classifier was used. Models were developed by WFBR.

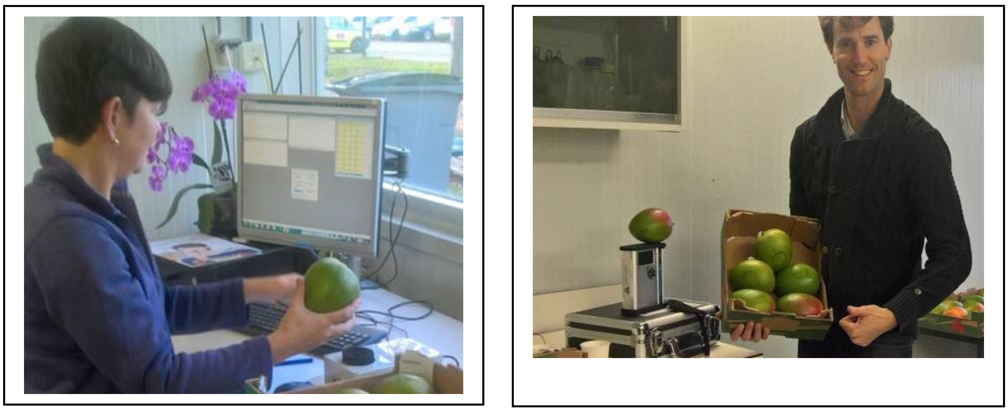


Figure 2.1: Example of firmness measurements using the Aweta (left) and an example of NIR measurements using the FELIX-F750 handheld (right).

Figure 2.2: Example of subjective/visual (left) and objective/instrumental (right) measurements of internal color.

Figure 2.3: Mango internal color scale for cv Kent from class 1 (white/light yellow) to class 5 (dark yellow/orange) (left picture). Example of Mango cubicles (right picture).

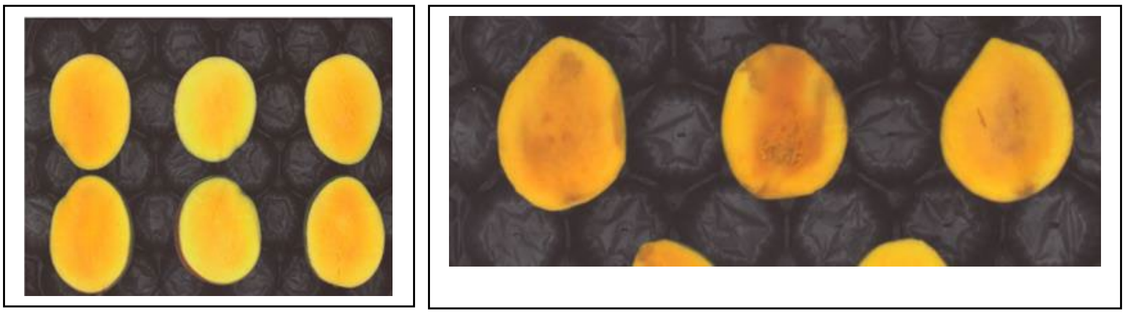


Figure 2.4: Standardized pictures to objectively measure internal color (left) and internal breakdown (right).

Table 2.1: Different Orchards from AGRODAN

Name of Orchard:	**Code of Orchard (for data tracing):**
Ilha Da Vazea	35
Ilha Da Vazea	44
Ilha Da Vazea	51
Ilha Da Vazea	32
Ilha Da Vazea	40
Ilha Da Vazea	30
Ilha Da Vazea	41
Ilha Da Vazea	77
Brandoes	02
Brandoes	07
Cachoeira	6.1
Cachoeira	6.2
Cachoeira	9.3
Ilha Grande	077
Ilha Grande	078
Frutos Da Ilha II DL	06

Table 2.2: Week of shipment from Brazil till dates of arrival at WFBR per shipment.

Shipment number:	**Week of shipment (2016):**	**Date of arrival:**
1	40	Oct 25 2016
2	41	Nov 1 2016
3	42	Nov 8 2016
4	44	Nov 22 2016
5	45	Nov 29 2016
6	46	Dec 6 2016
7	47	Dec 13 2016
8	47	Dec 13 2016
9	50	Jan 3 2017

3 Results and discussion

3.1 Experiment A: Predict Mango Quality by Firmness

The firmness of mangoes of the cultivar Kent decreases over time, for all orchards except Brandoes. Mangoes ripened at 20°C show a faster decrease of firmness compared to mangoes ripened at 16°C (figure 3.1 and 3.2).

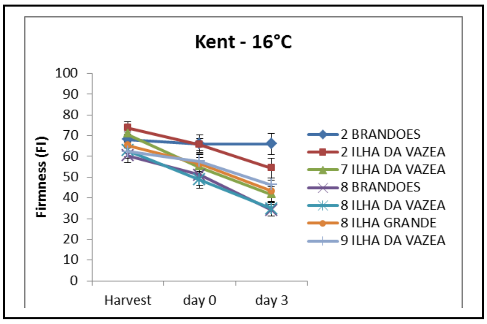


Figure 3.1: Average of firmness of mango cultivar Kent per orchard, measured at harvest day, day of arrival (day 0) and after 3 days of ripening at 16°C (day 3).

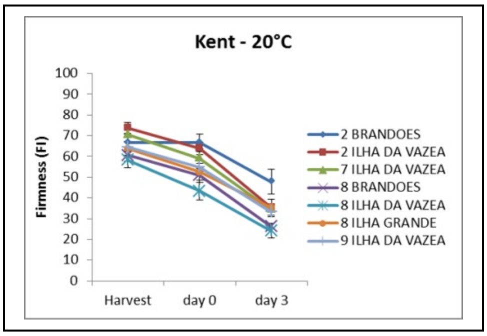


Figure 3.2: Average of firmness of mango cultivar Kent per orchard, measured at harvest day, day of arrival (day 0) and after 3 days of ripening at 20°C (day 3).

Also for the cultivar Keitt, the firmness of mangoes decreases over time, for all orchards. Mangoes ripened at 20°C show a faster decrease of firmness compared to mangoes ripened at 16°C (figure 3.3 and 3.4).

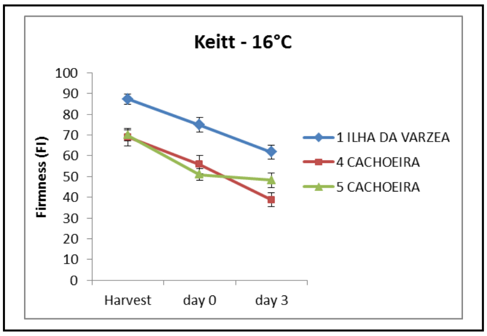


Figure 3.3: Average of firmness of mango cultivar Keitt per orchard, measured at harvest day, day of arrival (day 0) and after 3 days of ripening at 16°C (day 3).

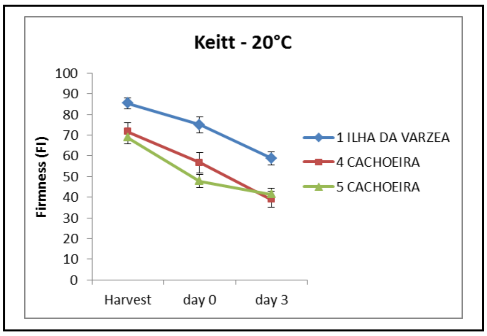


Figure 3.4: Average of firmness of mango cultivar Keitt per orchard, measured at harvest day, day of arrival (day 0) and after 3 days of ripening at 20°C (day 3).

To allow prediction of firmness at RTE stage, the firmness measured at day of harvest was correlated to the firmness at day 0 (day of arrival) and day 3 (RTE stage (after 3 days of ripening). Prediction of firmness at day 3 based on firmness at harvest results in an R^2 of 0.15 for Kent or 0.75 for Keitt. Prediction of firmness at day 3 based on firmness at day 0 results in an R^2 of 0.50 for Kent and an R^2 of 0.71 for Keitt (figure 3.5 and 3.6).

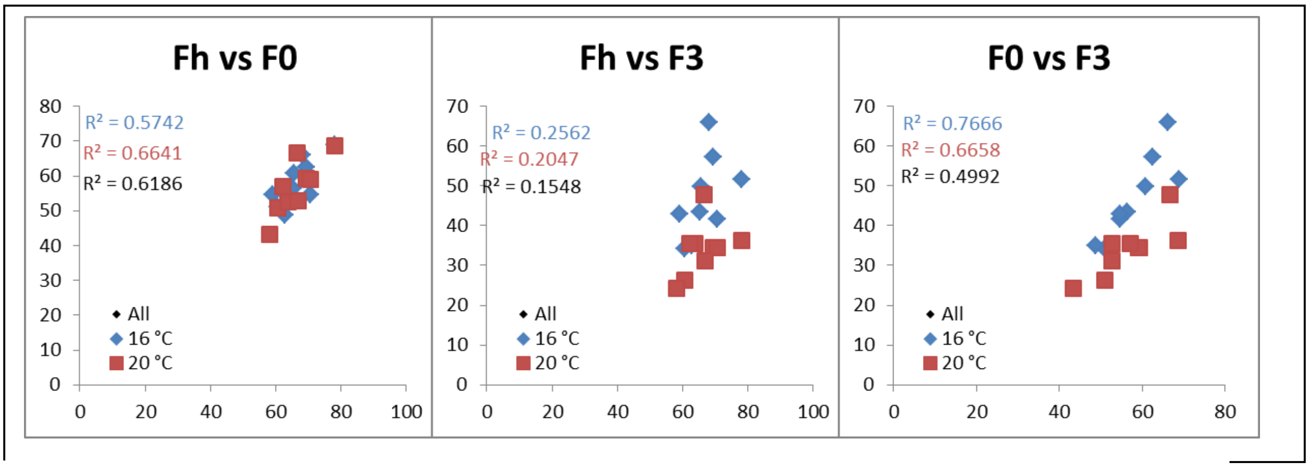


Figure 3.5: Firmness data of mango cultivar Kent for all shipments except shipment 3 and 6, and upon ripening at 16°C (blue) or 20°C (red). R^2 values indicate the predictive value.
Left picture: Correlating firmness at day of harvest (Fh) to predict firmness at day of arrival (F0).
Middle picture: Correlating firmness at harvest day (Fh) to predict firmness at RTE stage (after 3 days of ripening) (F3).
Right picture: Correlating firmness at day of arrival (F0) to predict firmness at RTE stage (after 3 days of ripening) (F3).

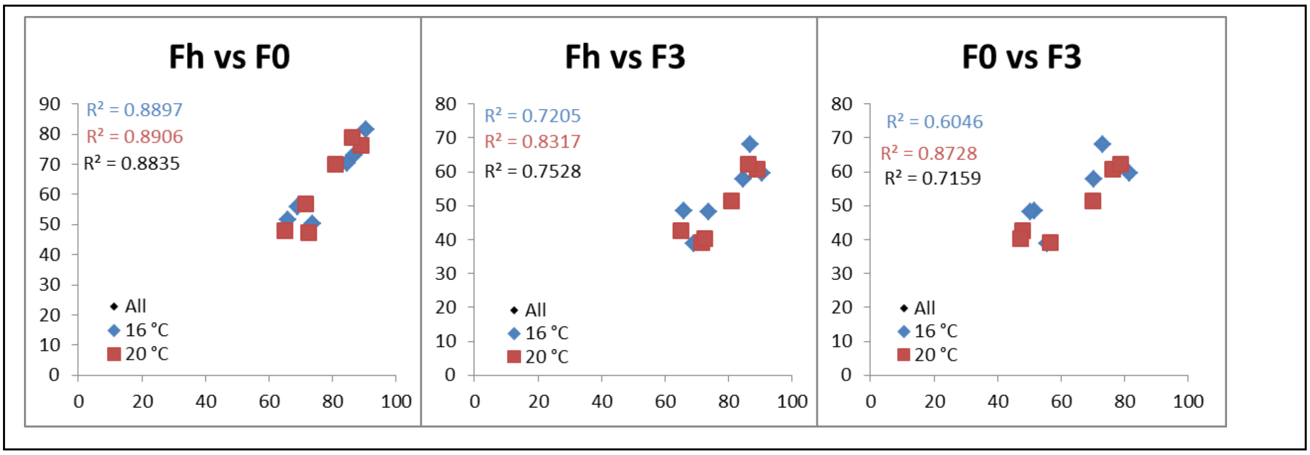


Figure 3.6: Firmness data of mango cultivar Keitt for all shipments except shipment 3 and 6, and upon ripening at 16°C (blue) or 20°C (red). R^2 values indicate the predictive value.
Left picture: Correlating firmness at day of harvest (Fh) to predict firmness at day of arrival (F0).
Middle picture: Correlating firmness at harvest day (Fh) to predict firmness at RTE stage (after 3 days of ripening) (F3).
Right picture: Correlating firmness at day of arrival (F0) to predict firmness at RTE stage (after 3 days of ripening) (F3).

<u>Firmness at RTE stage can be predicted using the following protocols:</u>

1) For Kent; by measuring firmness at day 0, taking into account whether ripening occurred at 16°C or 20°C.

2) For Keitt; by measuring firmness at day of harvest or day 0, irrespective whether ripening occurred at 16°C or 20°C.

3.2 Experiment A: Mango Quality and Color

Internal color, measured by "subjective" classification into class 1 (white/yellow) to class 5 (dark yellow/orange) (figure 2.3), shows a slight increase in mangoes ripened for 3 days at 20°C versus mangoes ripened at 16°C (figure 3.7). Mangoes ripened for three weeks at 16 °C were all classified as class 5 (dark yellow/orange) (data not shown)).

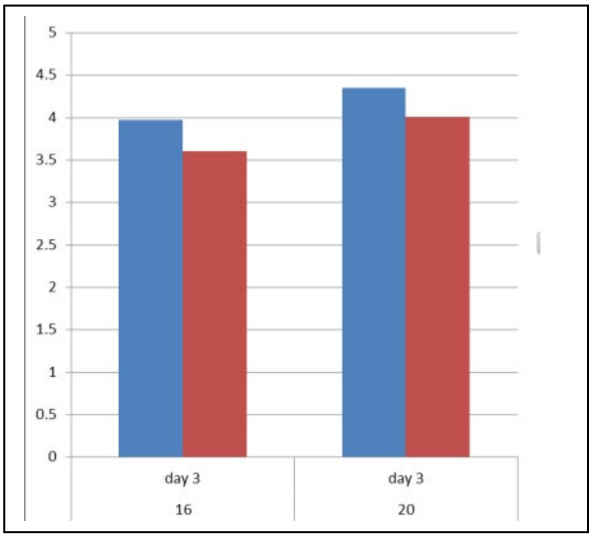


Figure 3.7: Average of internal color of mangoes from variety Keitt and Kent measured after 3 days ripening (day 3) at 16°C versus 20°C.

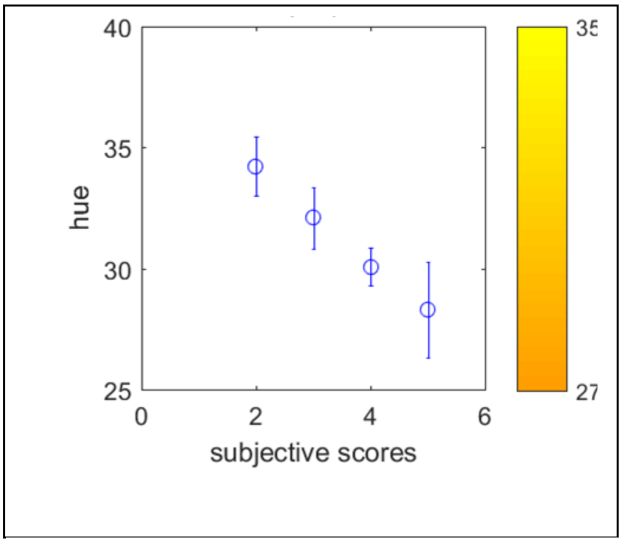


Figure 3.8: Color analysis by subjective classification in class 1 till 5 correlated to objective analysis of color pixels (hue values).

In addition, 96 mangoes from shipment 4 were also measured by analysing color pixels (hue values) in images taken under standard light conditions in a cabinet. Low hue values indicate dark yellow, and correlate to the mangoes visually scored in class 5. High hue values indicate light yellow and correlate to the mangoes subjectively classified in class 2 (figure 3.8). This indicates that objective phenotyping can replace subjective phenotyping (visual classification), providing more reproducible and reliable data.

3.3 Experiment A: Mango Quality and Internal Defects

Internal defects were quantified by estimating the percentage of cut surface which showed damage like internal browning, or in some cases corkyness. Although just a minor part of all mangoes showed internal defects, an increase in defects was observed in mangoes with a decreased firmness (figure 3.9). Furthermore, mangoes with a more dark yellow internal color (class 5) showed more internal defects. Moreover, the 1 cm^3 mango cubicles which were made to mimic "cut mango pieces" for VEZET, show an increase in internal defects when made from darker colored (more ripe) mangoes (figure 3.10). Mangoes were ripened for 3 days at either 16°C or 20°C. The percentage of internal defects is higher in the mangoes ripened at 20°C, indicating internal breakdown/ pulp browning is correlated to ripening (data not shown).

In addition to the original experimental setup as described in chapter 2, 96 mangoes from shipment 9 were stored for up till 7 weeks at 16°C or 20°C. Although most mangoes stored at 20°C showed complete decay, the mangoes stored at 16°C were still useable to measure internal breakdown. For both cultivars Keitt and Kent, the percentage of internal defects increases during storage at 16°C (figure 3.11). For a subset of the mangoes, the internal defects were also measured objectively, as the percentage of brown pixels in a standardized image (figure 3.12). Overall, we state that an increase of internal breakdown is observed in mangoes with a decreased firmness, an increased internal color and in mangoes stored at a higher temperature or for longer time. This confirms that internal breakdown is correlated to ripening.

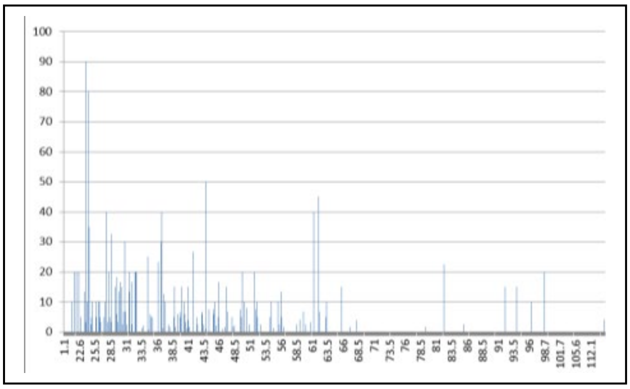


Figure 3.9: The average % of internal defects (y-axis) is increased in mangoes with a decreased firmness (x-axis)

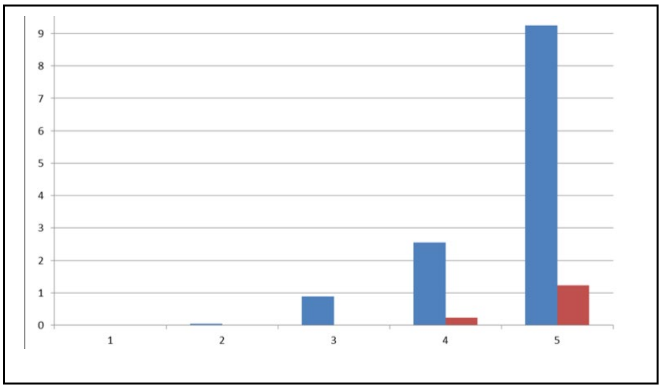


Figure 3.10: The average % of internal defects of mango halves (blue) and mango cubicles (red) is increased in mangoes with a more dark yellow internal color (class 5).

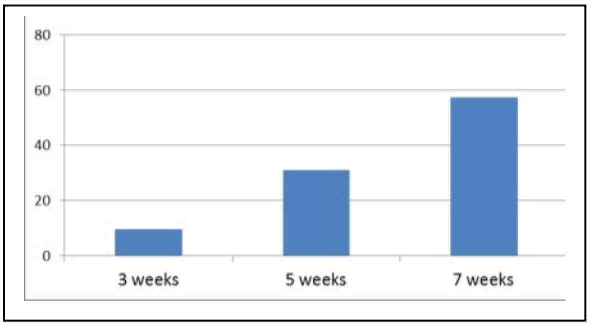


Figure 3.11: Internal defects as % of cut surface upon storage of 3, 5 and 7 weeks at 16°C.

Figure 3.12: Analysis of internal defects in standardized images to measure the percentage of internal defects (brown pixels) as % of cut surface.

3.4 Experiment A: Volatile Biomarkers for Mango Quality

Volatile measurements were performed on a set of 36 mangoes of the cultivar Keitt, all from shipment 4. The spectrum of produced volatiles changes after respectively one, three and six days of ripening at 20°C. A particular increase was observed for the volatiles of the ester family (known to cause fruity odours) (figure 3.13). To analyse the volatile spectra in a more extreme set of mango fruits, Bakker Barendrecht delivered 50 mangoes with low and high chances of internal defects based on their firmness. Among the mangoes classified in the set of "high chance for internal defects" the production of volatile esters was increased. Subsequent objective destructive measurements showed that indeed the % of internal defects was higher in the set of mangoes indicated as "high chance for internal defects" (figure 3.14).

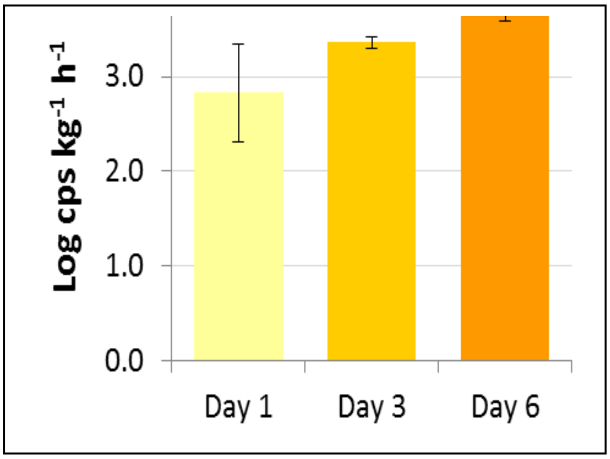


Figure 3.13: Increase of volatiles in the group of esters, during ripening at respectively 1, 3 and 6 days at 20°C.

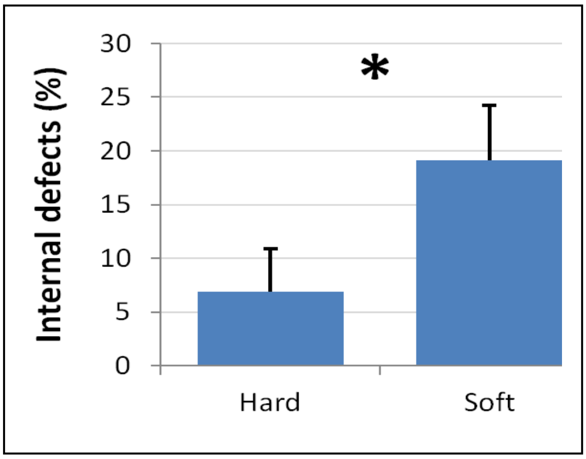


Figure 3.14: The % of internal defects in mangoes with low chance of internal defects (hard) versus high chance of internal defects (soft).

3.5 Experiment A: Predict Mango Quality by NIR measurements

From over 1500 mangoes from shipment five till nine, NIR spectra were measured. However, the NIR spectra show no correlations with the destructive BRIX and DM measurements using a standard PLSR (Partial Least Square Regression) model. Those NIR spectra are from a diverse set of mangoes (derived from different orchards, different shipments and diverse environment conditions). Therefore, it is difficult to find linear correlations between NIR spectra and the trait of interest (BRIX or DM). To narrow the diversity between the mangoes, NIR spectra of two specific sets were used to find correlations to firmness. Measurements on day 0 (day of arrival) from the set of 26 mangoes from cultivar Kent - from shipment 7 - orchard Ilha da Vazea, and the set of 26 mangoes from cultivar Keitt - shipment 5 - orchard Cachoeira show faint correlation (R^2 <0.5) for BRIX, DM and firmness using a direct neural network regression.

Instead of the "normal" regression models, which attempt to predict target variables directly, an alternative is to use a regression by comparison model. Such a model predicts target variables indirectly by comparing new NIR spectra with known NIR spectra (figure 3.15). By using a "regression by comparison" model we can compare firmness with 70% accuracy, BRIX with 89% accuracy and DM with 84% accuracy, using a neural network to perform comparisons. To allow proper sorting, further optimization of the predictive model is required.

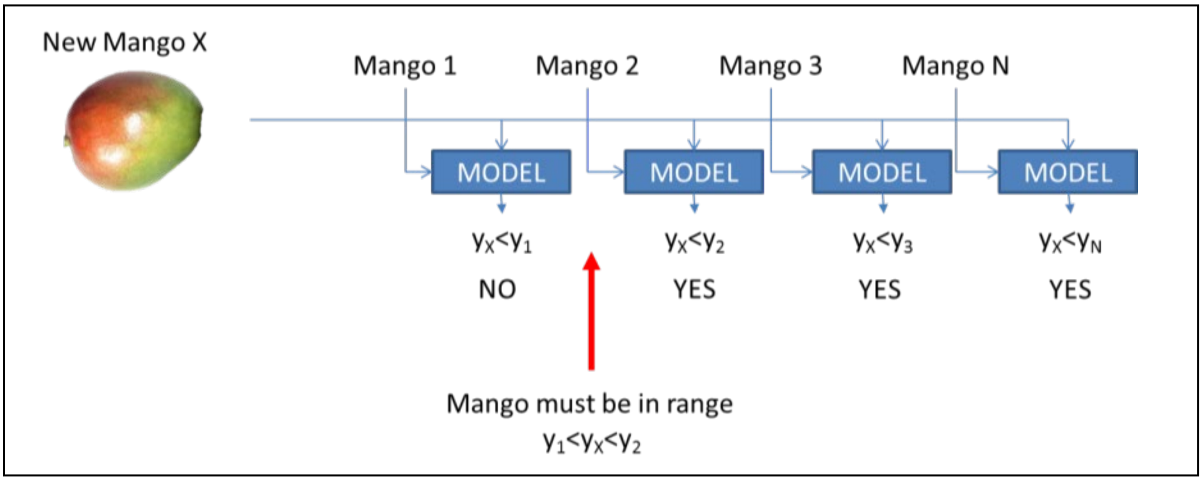


Figure 3.15: Regression by comparison model in which the firmness of each mango is predicted by comparing its NIR spectrum to NIR spectra of mangoes with known firmness.

DM and BRIX values, predicted by the NIR model generated by Martin Cedeño (Cedeño 2016) with an R^2 of 68% and 57% for respectively DM and BRIX, show a weekly increase from 5 weeks pre-harvest till arrival day and RTE stage (after 3 days of ripening) (figure 3.16). Pre-harvest NIR spectra follow the same change of amplitude in time (the shape of the raw spectra remains while the amplitude changes in time). This evolution of the spectra is an indication that we can track maturity (figure 3.17). Depicting each NIR spectra in a certain value/number, might provide us with a novel parameter to predict maturity (figure 3.18).

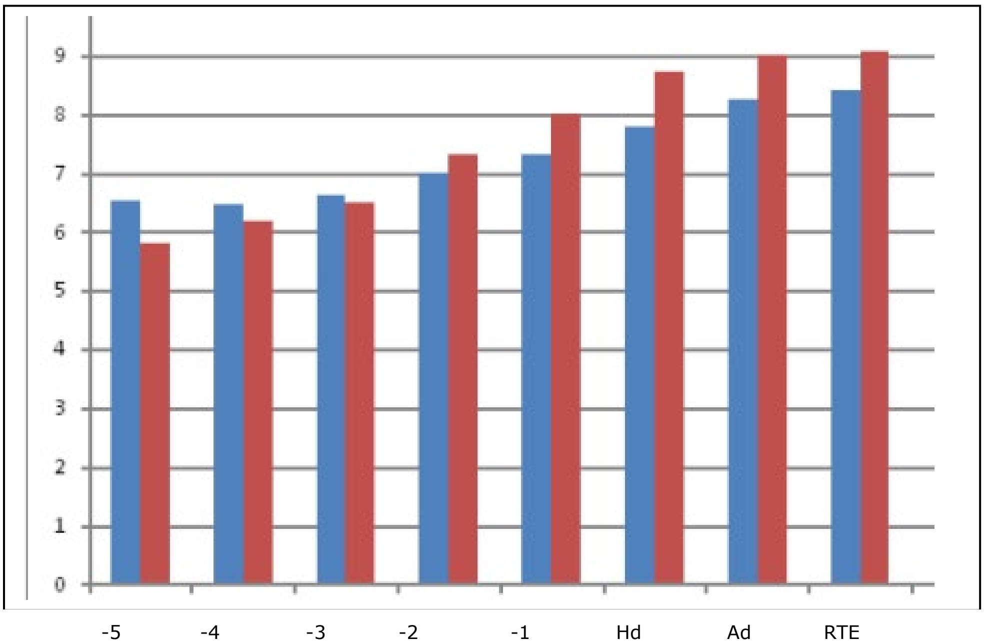


Figure 3.16: Average BRIX values from mangoes cv Keitt (blue) or Kent (red), measured weekly from 5 weeks (-5) pre harvest till harvest day (Hd), arrival day (Ad) and RTE stage.

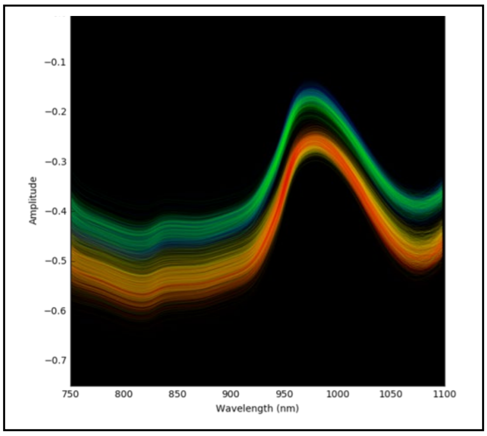


Figure 3.17: Average of NIR spectra of 100 mangoes measured weekly from 5 weeks pre harvest (indicated in blue) till RTE stage (3 days post ripening, indicated in red).

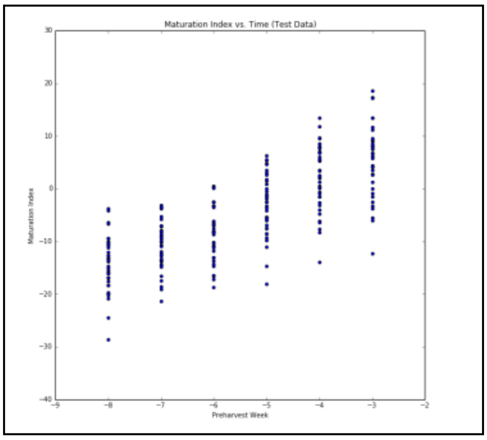
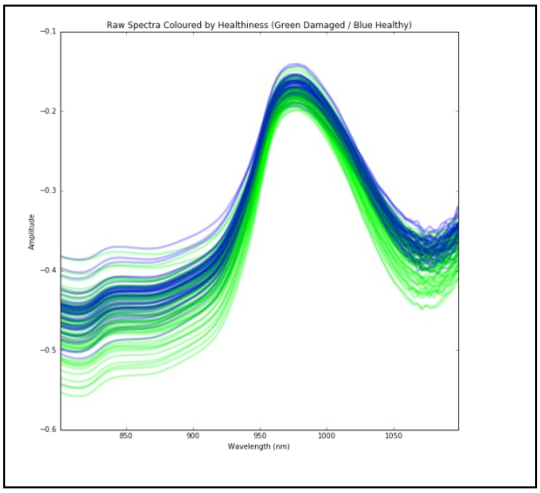


Figure 3.18: Weekly NIR spectra captured in values, indicating a significant change/evolution of NIR spectra in time.

3.7 Experiment 9AD: Defected versus Healthy mangoes

NIR spectra of 100 defected (with internal breakdown) versus 100 healthy mangoes show a clear distinction in two separate classes (figure 3.19). Based on their NIR spectrum mangoes can be classified as "defected" or "healthy" using a neural network model. Mangoes can be classified as "defected" or "healthy" based on their NIR spectrum, with an accuracy of 86%. Future investigation may include collecting data to provide an estimate of the probability of internal breakdown (necessary to accurately estimate risk in decision making) and disentangle interactions with mango maturity.



* 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.

Figure 3.19: NIR spectra of defected (green) and healthy (blue) mangoes, showing a distinction in two groups.

3.8 Experiment B: Quality and Transport (effect of precooling and genset)

Mangoes which were precooled fast (6 hours) before transport, showed a significant higher firmness, indicating fast precooling of the mangoes before transport has a positive effect on quality. The firmness of mangoes transported with a genset compared to mangoes transported without genset (figure 3.20) showed a non-significant difference. Therefore, the experiment regarding the use of the genset was repeated in shipment 5. Firmness was measured at the moment of harvest in Brazil and upon arrival in Wageningen. Again, no significant difference in firmness was observed between the mangoes transported to the port in a reefer "with or without genset" (figure 3.21).

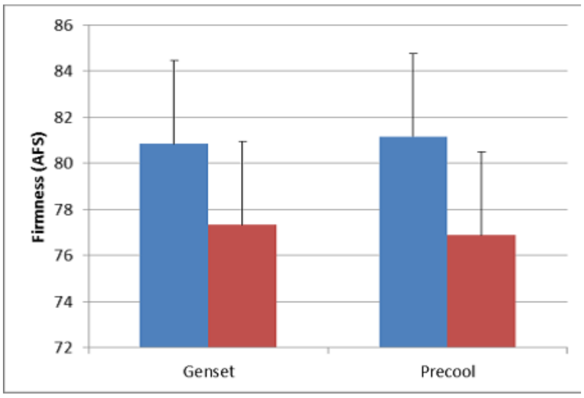


Figure 3.20: Mango firmness means of mangoes from shipment 1, measured at day of arrival in Wageningen, upon transport with genset (blue) versus without genset (red), and fast precooling (blue) versus slow precooling (red). Firmness is not significant different with/without genset. While firmness is significantly higher with precooling.

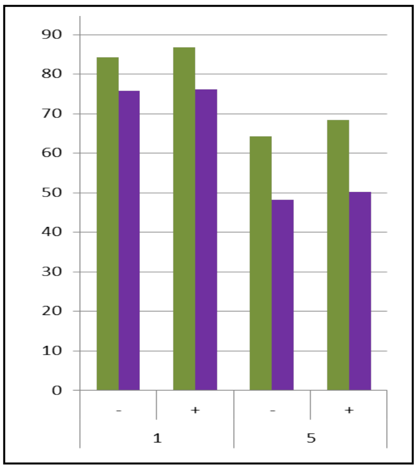


Figure 3.21: Averages of mango firmness of shipment 1 and 5, without (-) or with (+) genset, measured at the initial harvest day in Brazil (green) and day of arrival in Wageningen (purple), indicating no significant difference in firmness between mangoes transported with or without genset.

3.9 Environmental conditions Pre-Harvest (at orchard) and Post-Harvest (transport)

Loggers recording air temperature during transportation of the mangoes from harvest till arrival at WFBR show temperature variations prior to transport(figure 3.22), while temperature in the reefer container remained at a stable 10°C (data not shown). The use of chemicals, fertilizers, pH reducers and spreader stickers varies per orchard. An example of the variation of chemicals is shown in figure 3.23. 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.

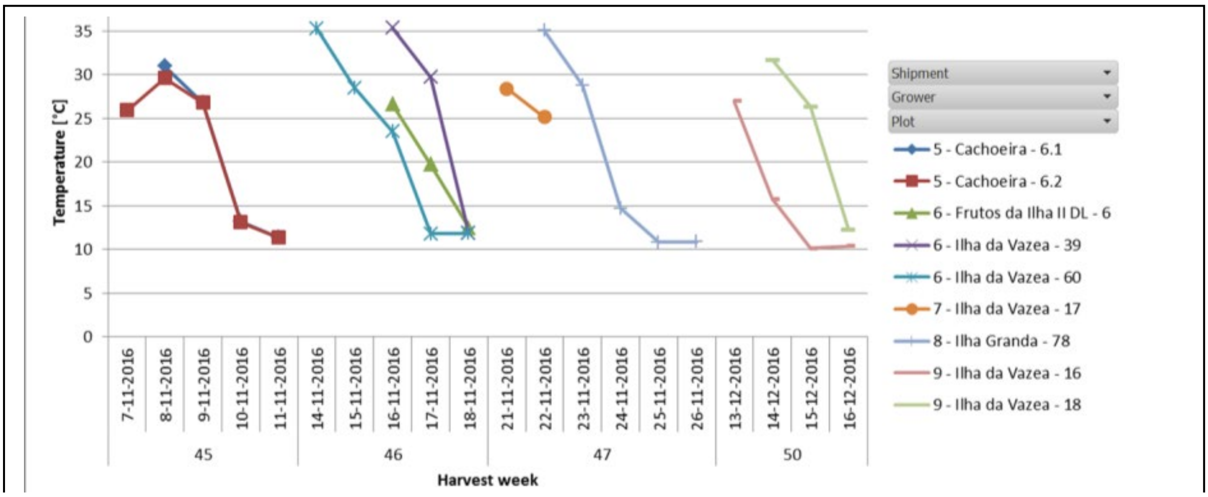


Figure 3.22: Temperature of loggers stored with the mangoes from the moment of harvest at the different orchards till arrival at Wageningen FBR, per week. Temperature at the moments of harvest vary from 25 till 35 °C, while temperature at during transport at the reefer containers remains approximately 10°C.

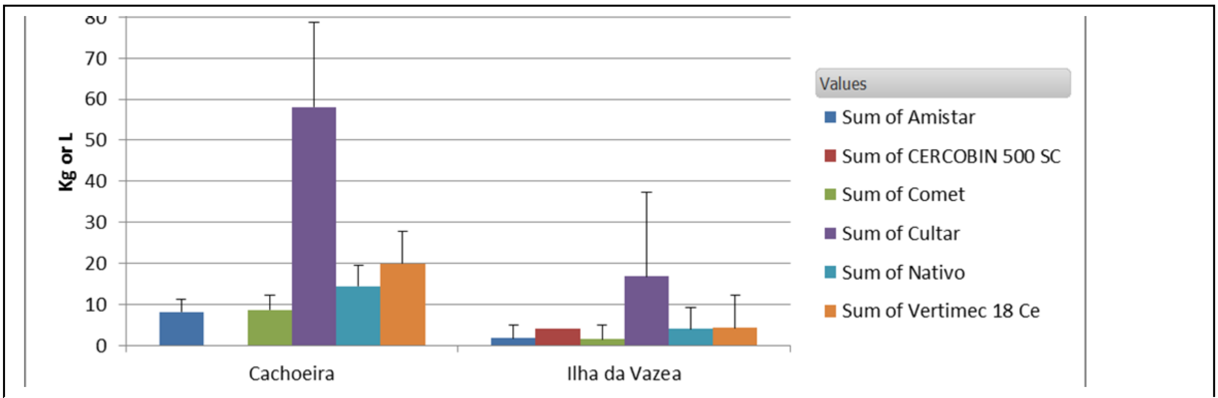


Figure 3.23: Variation in chemicals in orchard Cachoeira and Ilha da Vazea.

4 Conclusions and Recommendations

The quality of mangoes is based on traits like firmness, internal color or internal breakdown. To get insight in changes in mango quality during the distribution chain, several quality traits of more than 3000 mangoes were measured at different moments between harvest in Brazil, transport to The Netherlands and ripening. Measurements were done using subjective (visual) as well as novel objective measurements. In addition non-destructive measurements, like NIR spectra, were used to investigate the correlation with color, firmness, maturity, BRIX or DM values.

4.1 Firmness as a Key Trait to Predict Quality at RTE stage

Firmness is one of the key traits related to quality. Measuring firmness at different moments in the mango supply chain enabled us to develop a model to predict firmness in a future stage. Predicting firmness at RTE stage (after 3 days of ripening) of Kent mangoes is possible based on firmness measurements at day of arrival, irrespective whether ripening occurred at 16°C or 20°C. For Keitt mangoes, the firmness measured either at day of harvest or at day of arrival, allows prediction of firmness at RTE stage, irrespective whether ripening occurred at 16°C or 20°C (figure 4.1). **Prediction of RTE stage by firmness enables the delivery of more homogeneous batches, facilitating both supermarkets like AH as well as fruit processing companies like VEZET. More homogenous batches of mangoes allow more efficient handling of the product, less waste and finally a better and stable quality delivered to the final consumer.**

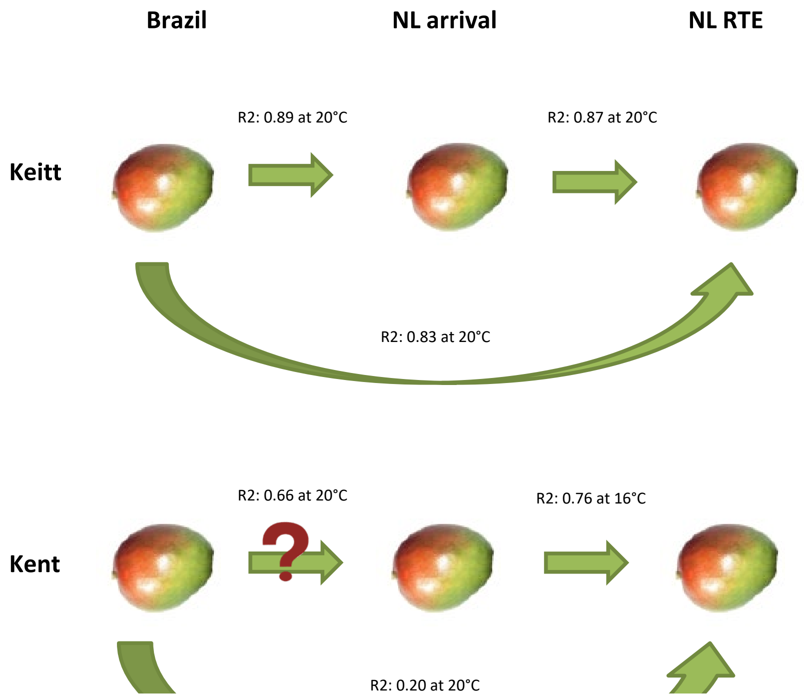


Figure 4.1: Firmness of Keitt mangoes at RTE stage in the Netherlands (NL) can be predicted by firmness measured at Brazil or upon arrival in the Netherlands (upper picture). Firmness of Kent mangoes at RTE stage in the Netherlands cannot be predicted by firmness measured at Brazil, but can be predicted by firmness upon arrival in the Netherlands (lower picture). R^2 values indicating the regression (correlation between the firmness measurements) at a certain ripening temperature are indicated above each arrow.

4.2 Standardized Internal Color Measurements

Besides firmness, internal color is used to determine the ripening stage of mangoes. As expected, internal color was higher after 3 days of ripening. In addition, in the mangoes ripened at 20°C the internal color was higher compared to the mangoes ripened at 16°C. However, a complete dark yellow color (class 5) was observed rarely. Only after "storage" of more than 3 weeks at 16°C or 20°C all mangoes could be classified in class 5, indicating a stage of ripe mangoes. These results confirm that internal color correlates with the ripening stage of mangoes.

The visual classification of mangoes by color is a subjective measurement, meaning that human judgement can cause variations (a mango classified as "3" could as well be classified in class "2" or "4"). To investigate objective phenotyping methods, images were made in a standardized "color cabinet". The color pixels were analysed using software and depicted as a high "hue value" for light yellow colors and a low "hue value" for dark yellow colors. Those objective measurements correlate with the subjective division in discrete classes, since the mangoes with low hue values were categorized in class 4 or 5, while the mangoes with high hue values were categorized in class 2 or 3. **Measuring color in an objective way not only reduces the variation due to human error, but also allows standardization of internal color measurements in a continuous scale, throughout the whole world wide supply chain.**

4.3 Internal Defects and Standardized Measurements

For most mangoes no or hardly any internal defects were observed. However, an increase in defects was observed in mangoes with a decreased firmness or an increased internal color. Furthermore, mangoes ripened at higher temperature showed more internal defects. Also longer storage (over 3 weeks at 16°C or 20°C) results not only in more ripened mangoes but also in mangoes with more internal defects (a higher percentage of brown color).
In addition to observations on cut mango halves, the effect of browning was observed on 1 cm^3 mango cubicles, which were made to mimic the "cut mango pieces" made by VEZET. Similar to the mango halves, hardly any browning was observed in the mango cubicles. However, an increase in browning was observed in cubicles which were made from mangoes with darker colored (riper) mangoes.
Internal defects were measured by cutting the mangoes in halves and estimating the amount of browning as percentage of the cut surface. This visual inspection is a quick, but rough measurement amenable for human error. For a subset of mangoes also objective measurements were done by analysing standardized pictures. Although these instrumental measurements are less high-throughput, they allow more accurate and reproducible measurements.
These results indicate that internal browning correlates to a decreased firmness, an increased internal color and storage for longer time or at a higher temperature. **Understanding the causes of browning and, more specific, determining the turning point of ripe versus brown mangoes helps to improve the current logistic chain by minimizing the practices that contribute to internal defects.**

4.4 Volatile Biomarkers for Mango Quality

Instead of destructive measurements, like observations on internal color or internal defects, non-destructive measurements to determine the quality of mangoes would be preferred. Measurements of volatiles would allow such non-destructive measurements. Ripe mangoes produce fruity odours which we can smell at a certain moment in the ripening stage. Volatile measurements, performed using PTR-ToF-MS on a sub-set of mangoes, indicate that the spectrum of produced volatiles changes during ripening. Particularly the production of volatiles in the group of esters (fruity odours) increases. Comparison of the volatile pattern between mangoes with low versus high chances of internal defects (based on their firmness) showed that mangoes with a high chance of internal defects produce more ester-volatiles. Subsequent destructive measurements showed an increase in the % of internal defects in the mangoes categorized as "high chance for internal defects" and producing more ester volatiles, compared with the "low chance for internal defects" mangoes. These results indicate that **volatile esters may be used as non-destructive biomarkers to detect ripe mangoes**. Since these measurements were done only on a small subset of mangoes, it is recommended to confirm these data on a larger set of mangoes. **Measurements over time might allow us to discriminate between volatiles correlated to ripening and volatiles correlated to internal defects.**

4.5 Predicting Mango Quality by NIR measurements

A novel method to detect mango quality using non-destructive measurements by reading NIR spectra was investigated. The FELIX-F750 handheld allows easy and fast reading of NIR spectra. This apparatus was purchased by WFBR end of November 2016, allowing us to perform NIR measurements on all mangoes received from shipment 5 (arriving December 2016) onwards. Prior to NIR measurements at WFBR, a subset of mangoes in Brazil was used to feed the FELIX-derived model and correlate the NIR spectra with DM and BRIX values (obtained using destructive measurements). Based on these measurements, a FELIX-linear regression model allowed the prediction of DM and BRIX with an R^2 of respectively 68% and 57% (Cedeño, internship report December 2016).
At WFBR, NIR spectra were measured from all mangoes received from shipment 5 till 9. However, when using a “standard” PLSR model, the NIR spectra do not correlate with BRIX and DM. Since all 1500 mangoes derive from different orchards, different shipments, different conditions, obtain different wax layers etcetera, it is difficult to obtain linear correlations from this large and diverse set of data. Therefore NIR spectra of two specific sets of 26 mangoes from the same cultivar, orchard and shipment, were used to find correlations to firmness. Although these two sets consist of less diverse mangoes, still just a faint correlation was observed, likely because the data set was too small.
Instead of a standard linear model, a “regression by comparison” model was used to compare each measurement with existing data. “Regression by comparison” can be based on a linear model (allowing extrapolation of the data), as well as on a so called “neural network”. Based on a neural network within the “regression by comparison model”, firmness, BRIX and DM values of new mangoes could be compared with those of known mangoes with an accuracy of 70%, 89% and 84% respectively. P**redictions of firmness/BRIX/DM based on NIR spectra allows non-destructive sorting of incoming mangoes to obtain uniform RTE mangoes at the shelf.** Further optimization by providing (“feeding”) the model with more data is required.

In experiment 9AB the quality of mangoes was tracked while they were growing on the tree, at the moment of harvest until RTE stage. Weekly NIR measurements show an increase in DM and BRIX during time, indicating increased maturity of the mangoes. The increase in maturity is reflected in the evolution of NIR spectra in time. From this we can conclude that, in addition to judging the maturity of mangoes by traits indirectly linked to maturity like DM, BRIX or firmness, we can track maturity by following the evolution of NIR spectra. For practical applications, using a regression model, the NIR spectra were captured in a value shown to correlate with measurement time. **The capture of NIR spectra in a value enables the use of each NIR spectrum as a marker to track maturity**.

Comparison of NIR spectra of defected (also called "collapso") mangoes with healthy mangoes showed a clear distinction in two groups. Based on the classification of the NIR spectrum of mangoes they can be predicted as defected or healthy with an accuracy of respectively 87 or 84%. From the NIR data obtained in this study, we can conclude that regular linear models are not useful to correlate NIR spectra of a diverse group of mangoes to specific traits. However, when using the alternative models, NIR spectra allow prediction of traits like firmness, BRIX and DM. In addition NIR spectra might allow the prediction of more abstract values like "maturity" and "defected" versus "healthy" fruit. **In summary, upon using appropriate models NIR measurements allow sorting of mangoes either 1) pre-harvest to determine the most optimal harvest moment, 2) post-harvest to discard defected fruit and 3) at the moment of arrival to sort mangoes based on maturity or firmness. Successful application of NIR measurements in combination with the proper sorting models, results in more uniform and RTE mangoes on the shelf.**

4.6 Mango quality in relation to Pre-Harvest and Transport Conditions

Pre-harvest conditions like rainfall, humidity, temperature, but also the use of fertilizers and chemicals were recorded during time and per orchard. Although variations between orchards could not be correlated to quality of the mangoes, insight in the variations could provide more information to agronomist. In addition transport conditions like temperature and humidity were recorded until arrival at WFBR. As expected transport temperature in reefers with genset remains approximately 10°C.

Experiments comparing precooling conditions indicated that mangoes which were precooled fast (6 hours) before transport, showed a significant higher firmness. Transport of mangoes to the harbour of Brazil in a reefer container with or without genset showed no significant difference in firmness. **These results show that precooling has a positive effect on quality of mangoes, while transport to the harbour with or without genset has no significant effect.**

5 References

Cedeño Pineda M. 2016: Internship Report Manual "Deliverables" regarding the procedures of the different tests made in AGRODAN Brazil, aiming to acquire reliable information that leads to the identification of the initial quality of the mango fruit in relation to the arrival at Bakker Barendrecht; all within the GreenCHAINge Project.

Holzinger R. 2015: A new widget tool for processing PTR-TOF-MS data

Pino J.A., Mesa J., Munoz Y., Marti M.P and Marbot R. 2005: Volatile components from mango (*Mangifera indica* L.) cultivars.

Westra E., Mensink M. and Pereira da Silva F. 2016: GreenCHAINge Fruit&Vegetables Workpackage 1: Brown coloration of cut mango fruit. Report 1663.

6 Acknowledgements

We thank Bakker Barendrecht for supplying the mangoes and especially Xiomara Salas and Erna van der Wal for providing all the details and the close collaboration. We would also like to thank the support of the AGRODAN team for the thorough preparation and measurements. Foundation TKI Horticulture, Albert Heijn, Bakker Barendrecht, MAERSK LINE and VEZET are acknowledged for the project funding.

Appendix A Short Reports

Defected versus Healthy Mangoes

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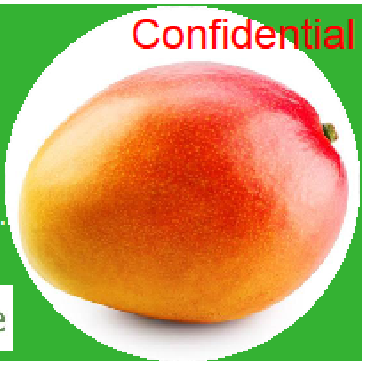
Defected versus Healthy Mangoes



Hendrik de Villiers, Suzan Gabriëls & Eelke Westra.
15-3-2017

WAGENINGEN UNIVERSITY & RESEARCH GreenCHAINge

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) mangoes on the shelf.
- Compare and predict "defected" versus "healthy" mangoes using non-destructive NIR (Near-infrared) measurements.

Results

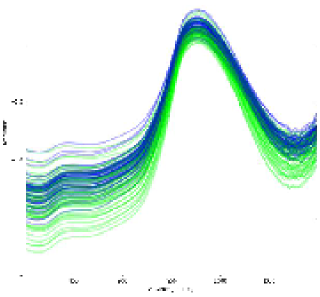
- Non-destructive NIR measurements using a FELIX-F750 handheld on approximately 100 "defected" mangoes (with internal defects) and 100 "healthy" mangoes, indicates that the NIR spectra can be divided in two separate classes.
- Mangoes can be classified as "defected" or "healthy", based on their NIR spectrum, 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, mangoes 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 mangoes reach the customer. This leads to an increase in quality and efficiency, while lowering costs for all parties throughout the whole supply chain.



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

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

Contact
Wageningen Food & Biobased Research
Eelke Westra
T +31 (0)317 48 02 08
Eelke.Westra@wur.nl

PO Box 17
6700 AA Wageningen

www.wur.nl/wfbr

Wageningen Food & Biobased Research | GreenCHAINge WP1 | Defected versus Healthy Mangoes

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Mango Quality and Color

GreenCHAINge WP1

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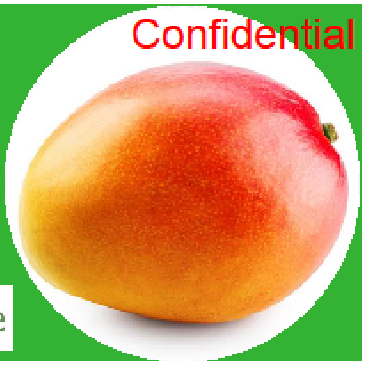
Mango Quality and Color

Suzan Gabriëls, Lydia Meesters & Eelke Westra.
8-3-2017



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) mangoes on the shelf.
- Determine the correlation of RTE mangoes with "internal color".
- Obtain an objective and reliable method to phenotype internal color.

Results

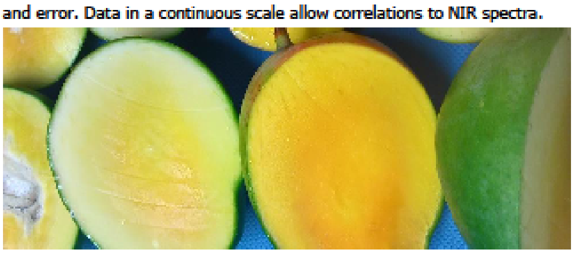
- Measuring the internal color of > 3000 mangoes transported from Brazil to the Netherlands, in 9 shipments between Nov '16 and Jan '17 shows that increased internal color (from class 1 (light yellow) to class 5 (dark yellow/orange) correlates with:
  - Decreased firmness.
  - Higher ripening temperature.
  - More internal defects/browning.
- "Objective phenotyping" by 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.

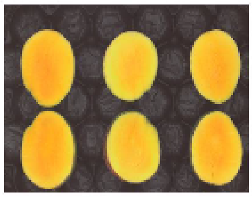
Conclusion

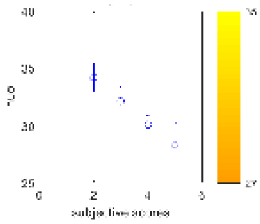
Internal color correlates with the ripening stage of mangoes. This can be measured more precisely with an objective camera system.

Relevant for industry

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

'Objective color measurements are more reliable and more useful for data-analysis'

Contact
Wageningen Food & Biobased Research
Eelke Westra
T +31 (0)317 48 02 08
Eelke.Westra@wur.nl

PO Box 17
6700 AA Wageningen

www.wur.nl/wfbr

Wageningen Food & Biobased Research | GreenCHAINge WP1 | Mango Quality and Color

Mango Quality and Internal Defects

GreenCHAINge WP1

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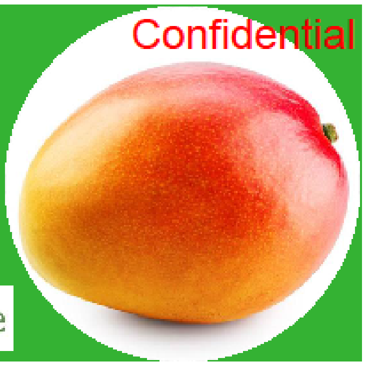
Mango Quality and Internal Defects



Suzan Gabriëls, Manon Mensink & Eelke Westra.
8-3-2017

WAGENINGEN UNIVERSITY & RESEARCH   GreenCHAINge

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) mangoes on the shelf.
- Understand reasons for internal defects like pulp-browning.
- Improve quality by controlling reasons for internal defects.

Results

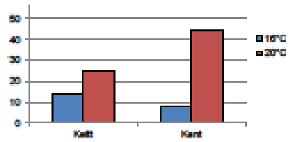
- Measuring the internal defects of > 3000 mangoes transported from Brazil to the Netherlands, in 9 shipments between Nov '16 and Jan '17 shows that pulp-browning correlates with:
    - Decreased firmness
    - Increased internal dark yellow color
    - Higher ripening temperature.
- Additional experiments showed that pulp-browning correlates with increased storage time
- Making 1 cm^2 mango cubicles to mimic "cut mango pieces" shows that an increase in internal breakdown correlates with browning of the mango cubicles.

Conclusion

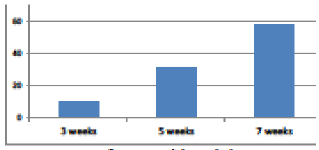
Internal pulp browning is most observed in ripe mangoes.

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.



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).

'Nice to see that the common hypothesis "browning correlates with ripening" is verified'

Contact
Wageningen Food & Biobased Research
Eelke Westra
T +31 (0)317 48 02 08
Eelke.Westra@wur.nl

PO Box 17
6700 AA Wageningen

www.wur.nl/wfbr

Wageningen Food & Biobased Research | GreenCHAINge WP1 | Mango Quality and Internal Defects

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Volatile Biomarkers for Mango Quality

GreenCHAINge WP1

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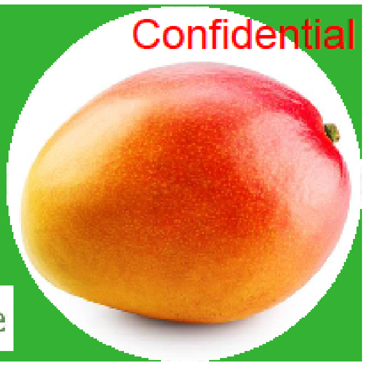
Volatile Biomarkers for Mango Quality

Bastiaan Brouwer, Suzan Gabriëls & Eelke Westra.
15-3-2017



WAGENINGEN UNIVERSITY & RESEARCH GreenCHAINge

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) mangoes 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

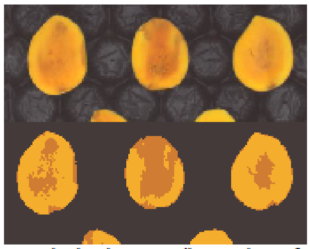
- Volatile measurements of 36 Keitt mangoes during the ripening process indicate that the profile of produced volatiles changes during ripening, particularly for volatiles of the ester family (known to cause fruity odours).
- Measuring volatile production, internal color and internal defects of 50 Keitt mangoes 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

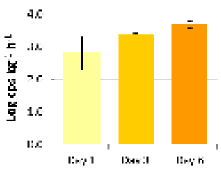
Ripe mangoes produce more volatile esters and mangoes that produce more esters show more internal breakdown.

Relevant for industry

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



Standardized images allow analysis of internal defects (brown pixels) as % of cut surface.



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

'Volatile esters may serve as biomarkers to detect internal

Contact
Wageningen Food & Biobased Research
Eelke Westra
T +31 (0)317 48 02 08
Eelke.Westra@wur.nl

PO Box 17
6700 AA Wageningen

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Predict Mango Quality by NIR measurements

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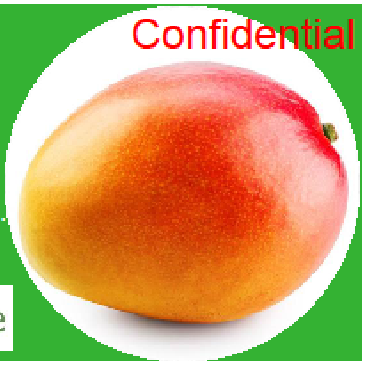
Predict Mango Quality by NIR Measurements

Suzan Gabriëls, Hendrik de Villiers & Eelke Westra.
15-3-2017



WAGENINGEN UNIVERSITY & RESEARCH GreenCHAINge

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

Objective

- Predict quality by non-destructive NIR (Near-infrared) measurements.
- Correlate NIR spectra to quality traits like firmness or DM (Dry Matter)

Results

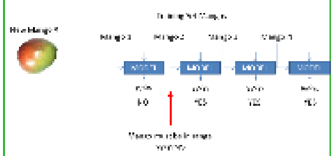
- Measuring NIR spectra of > 1500 mangoes at different time points between harvest at Brazil, transport to the Netherlands and ripening, shows that NIR spectra do not correlate to Brix and DM when using a regular "standard PLSR (Partial Least Squares Regression) model"
- NIR spectra of a specific batch of 26 mangoes (1 cultivar from 1 shipment and 1 orchard), measured at day of arrival, correlate faintly with firmness at day of arrival when using a PLSR model.
- Fortunately, the use of a "regression by comparison" model enables us to compare each measurement with existing data, allowing prediction:
    - Of firmness with 70% accuracy
    - Of BRIX with 89 % accuracy
    - Of DM with 84% accuracy

Conclusion

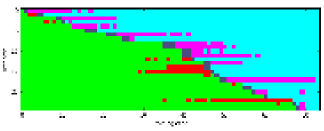
NIR spectra of an incoming batch of mangoes can be used to predict firmness/BRIX/DM, by comparison with NIR spectra of a batch of mangoes of which firmness/BRIX/DM is known. To allow proper sorting, further optimization is essential.

Relevant for industry

Sorting of mangoes based on your trait of interest is possible using non-destructive NIR measurements, when calibrating per batch of mangoes.



In a "regression by comparison" model each NIR spectrum is compared to NIR data of mangoes with known firmness, to predict its firmness.



Brix values of 25 mangoes are predicted by comparison with values of a batch of mangoes of which firmness is known. Correct prediction is indicated in green/magenta, false prediction is indicated in red/purple.

"Sorting of mangoes based on NIR spectra is possible using specific models"

Contact
Wageningen Food & Biobased Research
Eelke Westra
T +31 (0)317 48 02 08
Eelke.Westra@wur.nl

PO Box 17
6700 AA Wageningen

www.wur.nl/wfbr

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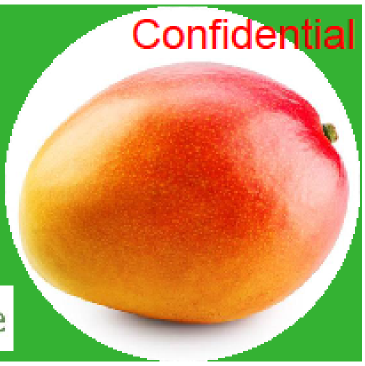
TOPSECTOR

Effect of Precooling and Genset

GreenCHAINge WP1

Effect of Precooling and Genset



Eelke Westra & Suzan Gabriëls
5-4-2017

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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) mangoes on the shelf
- Assess the effect of precooling mangoes before transport, and the use of a genset during transport, on mango quality

Results

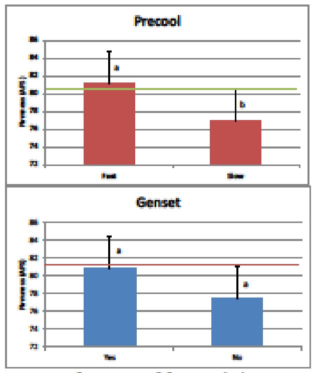
- When mango fruit is precooled fast (< 6 hours) the mangoes remain firmer than fruit that is precooled slower. A significant firmness decrease from 81 to 77 on the acoustic firmness scale was observed when measuring firmness after transport to the Netherlands.
- Using a genset (generator set) on the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



Average firmness of fast and slow precooled mangoes (red) and average firmness of transported mangoes using a genset yes or no genset (blue). Colored line and letters (a,b) correspond with significance level.

'Using a Genset over relative short distances is not always necessary when mangoes are proper precooled'

Contact
Wageningen Food & Biobased Research
Eelke Westra
T +31 (0)317 48 02 08
Eelke.Westra@wur.nl

PO Box 17
6700 AA Wageningen

www.wur.nl/wfbr

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TOPSECTOR

Predict Mango Quality by Firmness

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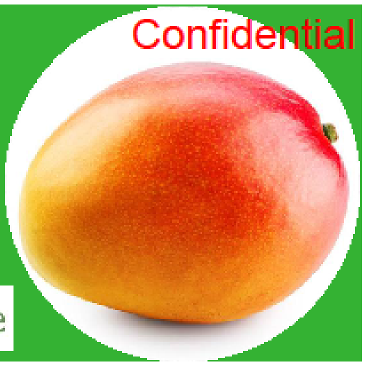
Predict Mango Quality by Firmness



Bastiaan Brouwer, Suzan Gabriëls & Eelke Westra.
8-3-2017

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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) mangoes on the shelf.
- Determine the correlation of RTE mangoes with "firmness".
- Predict quality by measuring the firmness at day of arrival.

Results

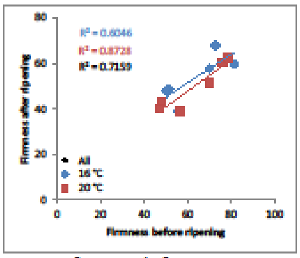
- Measuring the firmness of > 3000 mangoes at different time points between harvest, transport from Brazil to the Netherlands and ripening, in nine shipments between Nov '16 and Jan '17, shows that firmness is a parameter to predict the RTE stage of Mango cultivar Keitt and Kent.
- Firmness at "day of arrival" at Bakker Barendrecht correlates with firmness of RTE stage mangoes.
- A protocol to predict RTE stage is available for both Keitt and Kent mangoes based on:
    - Firmness at day of arrival.
    - Ripening at 16ºC or 20ºC.

Conclusion

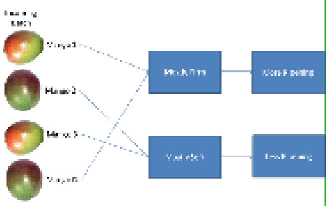
Delivering uniform and RTE mangoes on the shelf is possible by selection based on firmness at day of arrival at BakkerBarendrecht.

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.



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



'Selection based on firmness to deliver more uniform mangoes'

Contact
Wageningen Food & Biobased Research
Eelke Westra
T +31 (0)317 48 02 08
Eelke.Westra@wur.nl

PO Box 17
6700 AA Wageningen

www.wur.nl/wfbr

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Tracking Mango Quality Pre-Harvest until RTE stage

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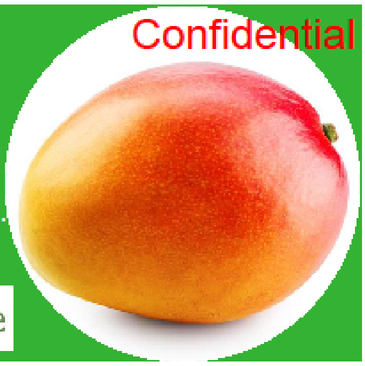


Tracking Mango Quality Pre-Harvest until RTE Stage.

Suzan Gabriëls, Hendrik de Villiers & Eelke Westra.
5-4-2017

WAGENINGEN UNIVERSITY & RESEARCH GreenCHAINge

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) mangoes on the shelf.
- Predict mango quality by measuring pre- and post-harvest traits.
- Track 100 Keitt and 100 Kent mangoes 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 BRIX (sugar content) with an r^2 (predictability) of respectively 68% and 57%, on 200 mangoes predict that DM and BRIX increase in time.
- Firmness data are too inaccurate to predict firmness by NIR.
- Pre-harvest NIR spectra from all 100 mangoes 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 BRIX.

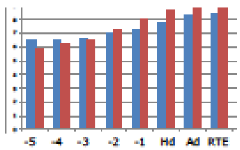
Conclusion

Instead of indirect tracking maturity (via traits like DM, BRIX or firmness), we can directly track maturity by capturing values of NIR spectra!

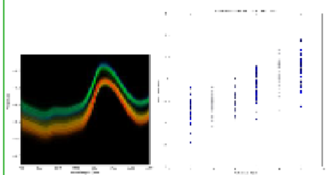
- Holds true when weekly measuring at the same mango spot.

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.



Brix values increase weekly from 5 weeks (-5) pre harvest day (Hd) till arrival day (Ad) and RTE stage.



NIR spectra ("dark blue/green" 5 weeks pre harvest till "red" (RTE)) correlate with maturity (left picture) and can be captured in values (right picture).

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

Contact
Wageningen Food & Biobased Research
Eelke Westra
T +31 (0)317 48 02 08
Eelke.Westra@wur.nl

PO Box 17
6700 AA Wageningen

www.wur.nl/wfbr

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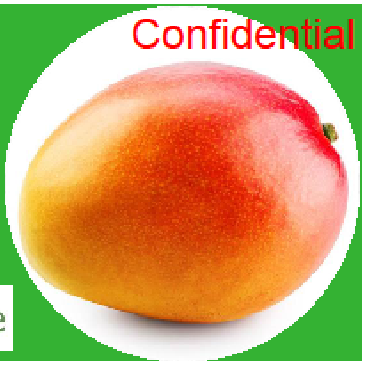

Pre-Harvest Factors Effect on Post-Harvest Mango Quality

Eelke Westra & Suzan Gabriëls
19-4-2017

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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) mangoes 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

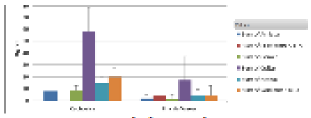
The temperatures between harvest and start of the transport per reefer container differed for each shipment. On some occasions mangoes remained warm (>15 °C) for more than 48 hours before being pre-cooled and transported.

Conclusion

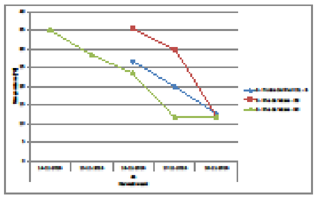
Since there is a difference in the usage in 16 pre-harvest treatments it is not possible to pinpoint one particular solution to post-harvest quality. Although no strait forward correlations could be identified, insights in variation and temperature management provide useful information for agronomist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



Variation in used chemicals per orchard for the same time period in orchard Cachoeira and orchard Ilha da Vazea



Daily average temperature for mangoes in shipment 2 between harvest (14 till 16 Nov '17) and reefer shipment (18 Nov '17) originating from three orchards

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

Contact
Wageningen Food & Biobased Research
Eelke Westra
T +31 (0)317 48 02 08
Eelke.Westra@wur.nl

PO Box 17
6700 AA Wageningen

www.wur.nl/wfbr

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