FOOD & BIOBASED RESEARCH
WAGENINGEN UR

GreenCHAINge Fruit & Vegetables

Work package 1: Brown coloration of cut mango fruit

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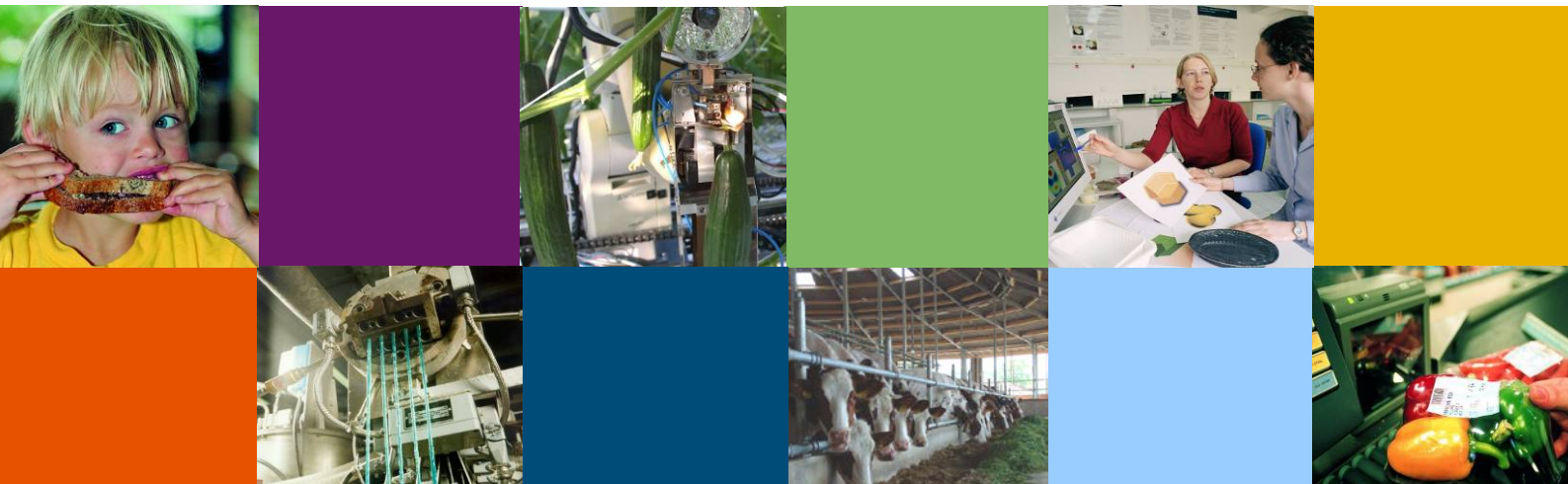
Report 1663



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Abstract

In the GreenCHAINge project Wageningen UR Food & Biobased Research works together with industry to get a better performance of quality for fresh fruits and vegetables. For mango, one of the problems limiting shelf life is brown discoloration of the fruit flesh after cutting. The objective is to understand the cause of brown discoloration of mango fruit flesh.

In a brown-insensitive period (March) and -sensitive period (April) harvested mangoes (Kent) were air freighted to the Netherlands. Two different fruit sizes and two different maturity stages were used. The fruit was additionally stored at two different temperatures (9 and 14°C) for three weeks, while fruit from the same original harvested batch was sea freighted to the Netherlands. On arrival (or after storage) the fruit was assessed for brown discoloration, internal maturity and firmness.

Late harvested mango fruits (April) have more brown discoloration than the early harvested mango fruit (March). (Determining the exact turning point is not the objective of this experiment, this can be tested as part of the monitoring programme in GreenCHAINge.)

In the April experiment, a higher simulated transport temperature of 14°C to prevent chilling injury showed significantly more internal browning than the simulated transport temperature of 9°C. In the March experiment, no brown discoloration was observed in the simulated transport temperature of 9°C nor in the 14°C. Therefore it is unlikely that chilling injury is causing the brown discoloration of the fruit flesh.

Large size mango fruit (S4) had significantly less browning than the small size (S6) fruit.

Brown discoloration of the mango fruit flesh is correlated with the internal maturity stage. The more mature the fruit is, the more issues can be found with regard to brown discoloration. The internal maturity status is usually assessed by cutting the fruit in half and evaluating the internal color of the fruit flesh. However this is a destructive measurement. Acoustic firmness was also measured before cutting as a non-destructive measure for firmness. Fruit that was harvested later in season had no external signs of further development, and by hand, all fruits felt firm. The firmness readings with the acoustic sensor revealed that in late season (April) the fruit was initially already softer. The acoustic firmness correlates with the internal maturity stage. In addition, the initial firmness reading corresponds for 45% with the end maturity stage (depending on storage temperature). The maturity stage as estimated by the supplier in M2 and M3 classifications had no significant relation with internal maturity stage nor with brown discoloration. Therefore, acoustic firmness measurements are a first step towards a better classification of mango fruit.

The maturation of mango fruit is strongly depends on temperature. The higher the transport or storage temperature, the more the fruit will mature.

For cutting mango as a fresh packed convenient food a certain maturity is preferred, because of taste, texture and firmness. However, more mature fruit has more issues with respect to brown discoloration. The right balance between the two should be found for the optimal solution..

Content

1 Introduction

In the GreenCHAINge project Wageningen UR Food & Biobased Research works together with industry to get a better performance in quality of fresh fruits and vegetables. The focus in work package 1 is on three important crops: Green Bean, Table Grape and Mango. The main research questions are:

I. How can initial quality, shelf life and quality be measured and predicted?
II. What is the influence of environmental conditions (e.g. temperature and humidity) and handling on the quality and shelf life?
III. How can, by understanding specific product related problems, quality and shelf life be improved?

For mango one of the problems limiting shelf life is brown discoloration of the fruit flesh after cutting. It is not understood why in certain periods the fruit turns brown and in other periods the problem does not occur. In expert meetings in 2016 the following hypotheses came forward:

1. Brown discoloration of the fruit flesh is depending of time in the season (early / late)
2. Brown discoloration is due to a too low storage temperature (chilling injury)
3. Brown discoloration is due to a unbalance in nutrients
4. Large fruit have more problems with brown discoloration than smaller fruit

The objective is to understand the cause of brown discoloration of mango fruit flesh.

2 Methods

2.1 Variables

To test the hypotheses, mango fruit was assessed during a brown-sensitive (April) and a brown-insensitive period (March). Part of the fruit was shipped commercially in 40ft. reefer containers and part was flown in by airplane and stored for an equal period as the reefer shipment. The storage of the mango fruit was executed at two temperatures: 9°C and 14°C. The higher temperature was applied to exclude chilling injury as a possible cause of brown discoloration. The regular shipment temperature is 9°C.
After storage and shipment the fruit was ripened for three days at 20°C.
After storage, shipment and ripening, the mango fruit was cut in half and stored at 6°C. Brown discoloration was assessed on the day of cutting, after one day and after three days (Table 1).

Table 1: variables tested in the experiment and assessment intervals

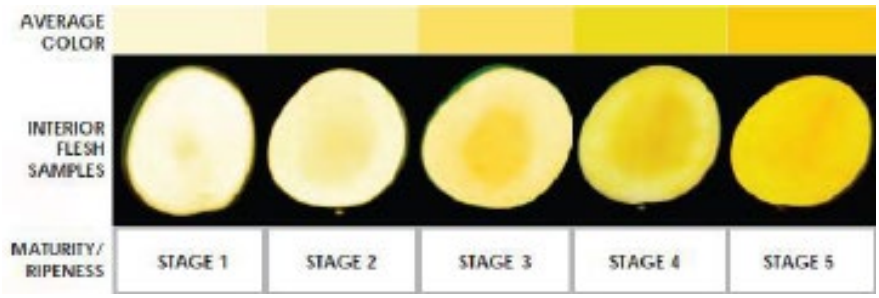
Variables	Description				
Season	March	April			
Transport method	Air freight	Sea Freight			
Storage	3 wks, 9°C	3 wks, 14°C			
Ripening	20°C for 3 days				
Assessments	At arrival	After ripening	After cutting	1 day after cutting	3 days after cutting

2.2 Product

The mango fruit originated from a commercial orchard in Peru. The "Kent" variety was used in two sizes S4 with an average weight of 0.9 kg and S6 with an average weight of 0.7kg. Two ripeness stages as classified by the suppliers (M2 and M3) were used.

2.3 Assessments

Before starting the storage period the mango fruit was tested for firmness using a AWETA acoustic firmness sensor (AFS). This gives a measure for initial ripeness of individual fruits. After storage and ripening the firmness was measured again with the AFS.
After cutting the internal maturity stage is assessed using a color chart (Picture 1) ranging from 1 to 5, 1 unripe (white flesh) and 5 ripe (yellow flesh).



Picture 1: Internal flesh maturity scoring chart

Brown discoloration was assessed on a 0 to 4 scale, 0 no discoloration and 4 75-100% brown flesh).

2.4 Nutrients

To test for differences in fruit nutrients, samples were taken of brown flesh and non-brown flesh and send to a laboratory for analysis of calcium, potassium and nitrogen Of the first experiment, four mangoes were tested at a commercial laboratory (Merieux NutriSciences). Two mangoes had no discoloration and two mangoes had brown flesh under the peel. The peel was removed from the mango fruit and 0,5 mm of flesh tissue under the peel was removed and stored at -24°C.

2.5 Analysis

The data was statistically analysed using Genstat® 18th edition version 18.1.0.17005. The method used was Linear Mixed Models because of the unbalanced design of the experiments. A p-value of <0.05 was used to determine significant differences.

3 Results

In the first experiment in March 2016 no brown discoloration of the fruit flesh was observed. In the second experiment in April 2016 a lot of the fruit was affected by brown discoloration after cutting (Figure 1 and annex).

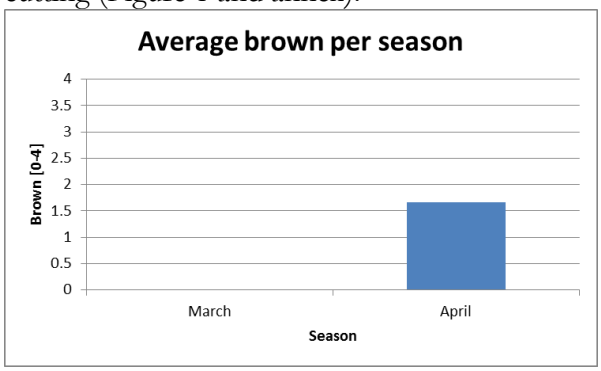


Figure 1: Average brown score over all treatments in the March and April experiments

3.1 Internal maturity stage

From the fruit assessed in April a clear relation was found between the degree of brown developed in a fruit after cutting and the internal maturity stage of the fruit. Fruit that was more developed internally had more brown discoloration (Figure 2).

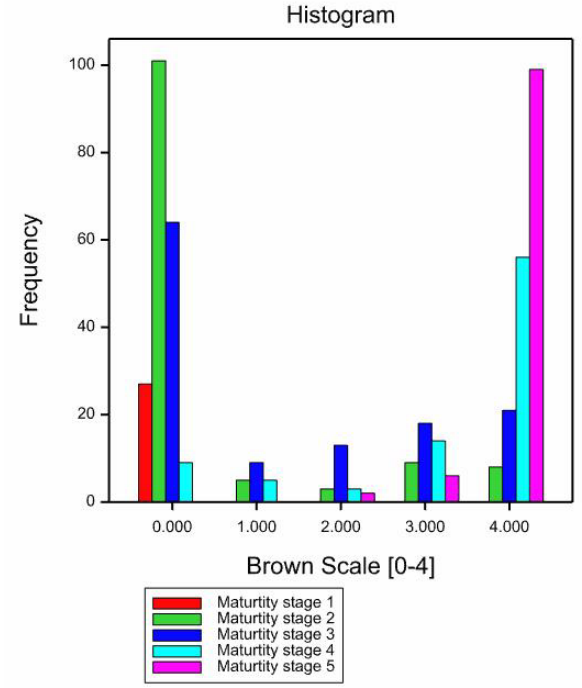


Figure 2: Amount of mango fruit with internal brown discoloration on a 0-4 scale 3 days after being cut in half per internal maturity stage

No fruit in an immature stage 1 had any brown discoloration whereas most of the mature fruit in stage 5 had severe brown discoloration.

3.2 Firmness

3.2.1 Firmness after storage/transport

The fruit firmness as measured with the AWETA acoustic firmness sensor showed a relation with the internal maturity stage. On average fruit having a lower firmness reading on the AFS are more ripe.
Figure 3 shows the boxplot of fruit firmness in the different ripeness stages .
For firmness readings below 20 internal ripeness stages have been found of 2, 3, 4 and 5, but predominantly more of these fruits are in stage 5 than in stage 2. For fruit with firmness readings above 40 the internal ripeness stage is more likely to be 1, 2 or 3.

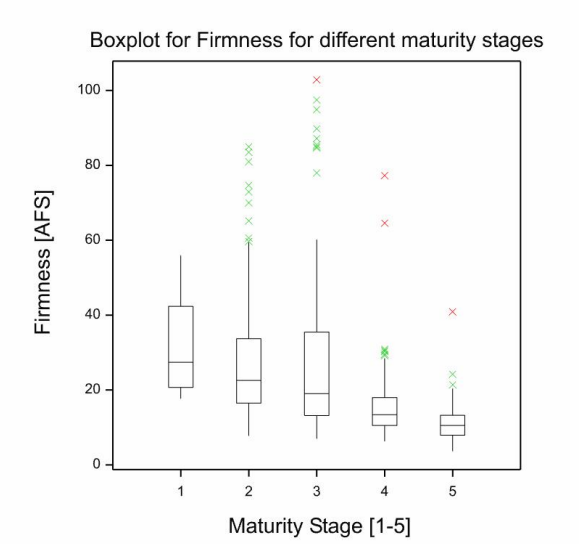


Figure 3: Acoustic firmness of mango fruit per internal ripeness maturity stage (data represent medians ± 2nd and 3rd quartiles within the boxes, whiskers are 1st and 4th quartiles, crosses are small (green) and large (red) outliers, n≥27)

While in the previous section we have shown that brown discoloration is found in fruit that is more ripe, here we showed that riper fruit is more likely to be softer.

3.2.2 Initial firmness

Because a non-destructive method was used for measuring initial firmness, , the fruits firmness readings could be followed in time before the fruit was cut to determined internal color an d brown development. In the previous section we have shown that firmness is linked to internal ripeness and brown discoloration.

The data shows that mango fruits with a higher initial firmness, measured before storage, have a higher probability to end up in a less mature internal ripeness stage and fruit with a lower initial firmness develop during storage in a more mature fruit (Figure 4). This of course depends on the conditions during storage.
Lower storage temperatures allow fruit with a lower initial firmness readings to end up with the same internal color as fruit with higher readings stored at higher temperature

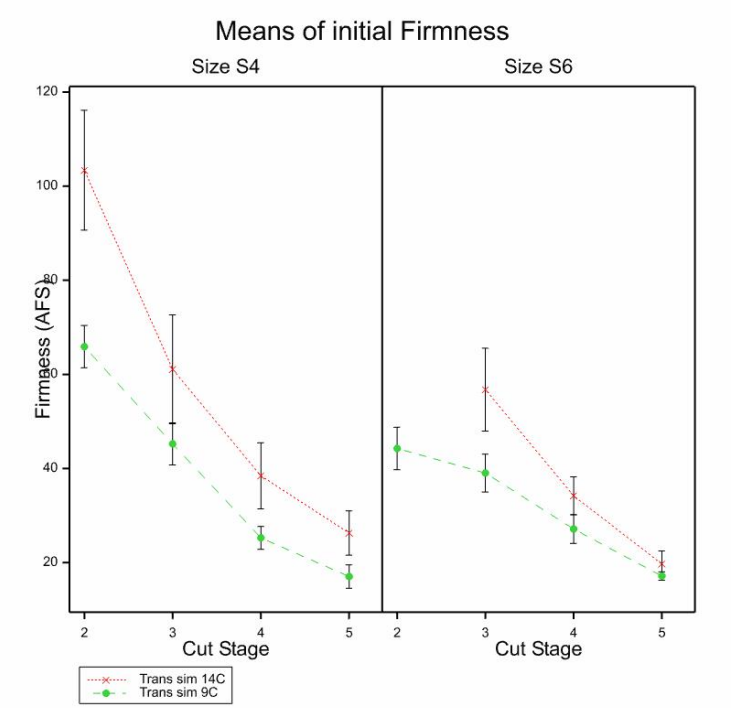


Figure 4 Initial Firmness of mango fruit corresponding with an end internal color stage (cut stage) after transport simulation of 14 and 9 ° Celsius per fruit size

The initial firmness readings explained 45% of the variation (regression analysis) in internal maturity stage, without damaging the product. The ripeness levels estimated/classified by the supplier , directly after harvest, had no predictive power at all. The internal ripeness stage for M2 fruit was after storage 3.98 and for M3 fruit 4.02 (LSD 0.24).

Based on this data it seems possible to use initial firmness, measured with AFS, as a selection criteria, to predict development of internal colouring stage. This is a first step towards a predictive model where for now a firmness reading of 33 after airfreight (at arrival) seems to be the threshold between mangos for a higher change of turning brown.

3.2.3 Firmness difference in harvest 1 and harvest 2

The difference between the first and the second experiment is the firmness level with which they arrived in Wageningen, after air freight and sea shipment. The first batch arrived with a firmness between 50 and 60 (AFS) and the second batch arrived with a firmness between 30 and 40 (AFS), meaning softer (Figure 5). This relatively low firmness of the second batch of mangos suggests that a considerable amount of these mangos had an increased chance of turning brown already at arrival.

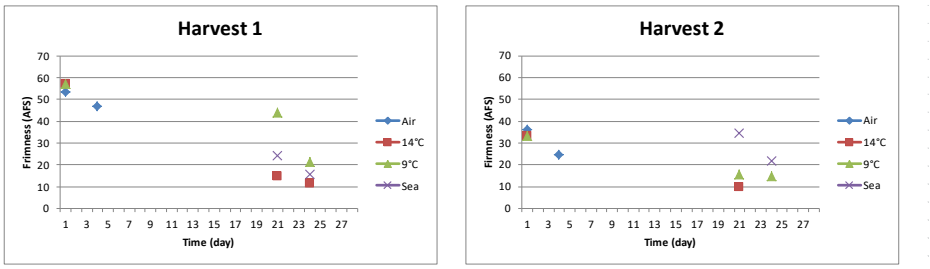


Figure 5: Firmness of mango fruit for harvest 1 and harvest 2. Harvest 1 was in March 2016, Harvest 2 was in April 2016.

3.2.4 Firmness and brown relation

The percentage of variation accounted for by initial firmness on brown discoloration is 27%. This is not a very strong correlation. Figure 6 shows that most brown fruit is soft, but there is a lot of variation overall

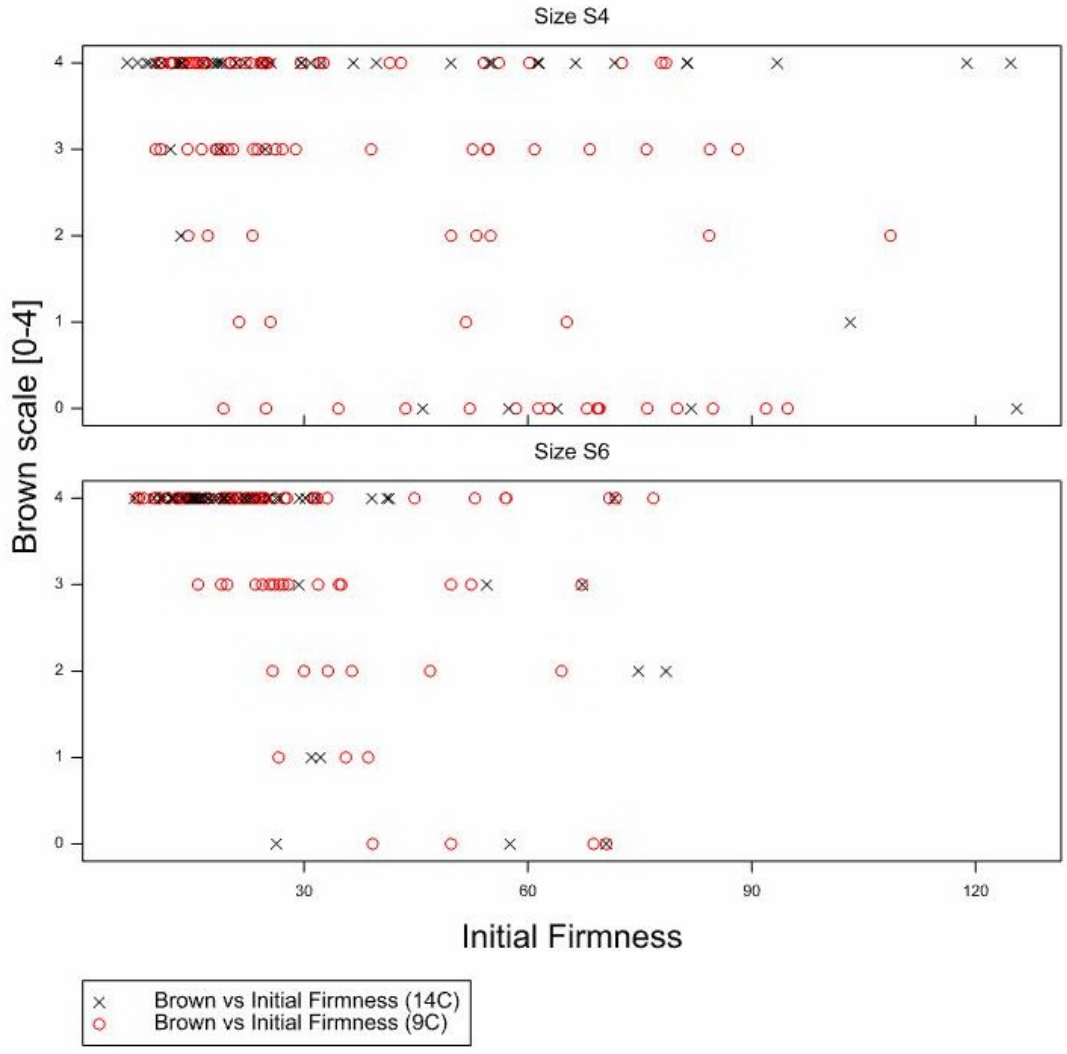


Figure 6: Brown discoloration in relation with initial firmness split per size group and for different transport temperatures.

3.3 Size

Small size mangoes (S6) show more browning compared to large size mangoes (Figure 7).

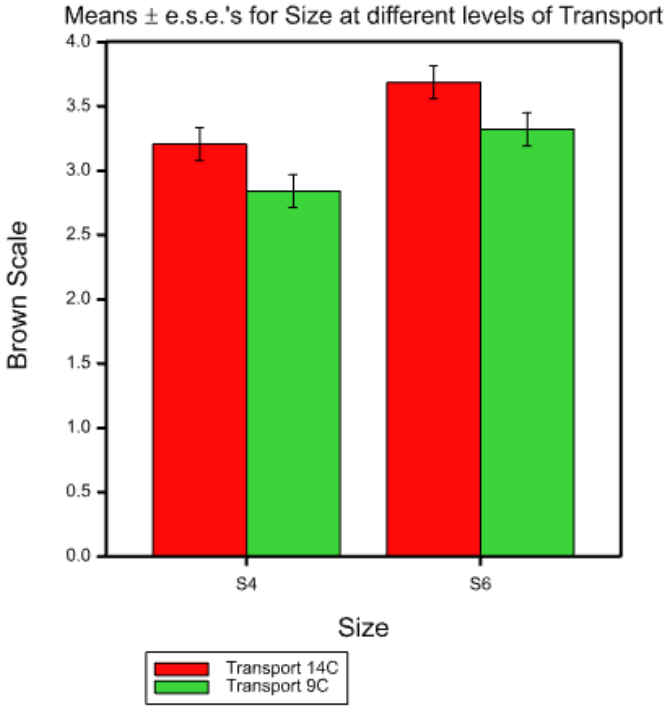


Figure 7: Brown discoloration per size group and transport temperature

Smaller sized fruits were 11 points of firmness softer prior to the transport simulation , compared to the larger sized fruits (28.2 vs 39.5).

3.4 Temperature, transport method & ripening

Higher storage temperature results in more mature fruit and simultaneously in more brown discoloration in the fruit (Figure 8). Mango fruit shipped commercially via air freight or sea freight had limited problems with internal browning. Although the temperature was relatively high for the air shipment (±25°C) the speed of transport caused the mango's did not mature too much. Storing the fruit after air freight at sea freight temperature caused the fruit to mature more than the fruit that arrived by sea freight. This is was also reflected in the firmness at arrival (Figure 5). Regarding sea freight, there was no difference observed between different size fruit in internal browning.

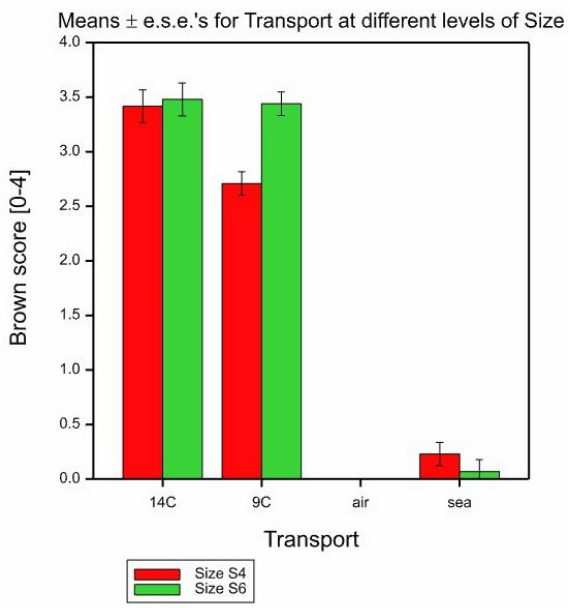


Figure 8: Brown discoloration per transport temperature and size

3.4.1 Ripening

The additional 3 days at 20°C had very little additional effect on brown development. This could only be tested on the fruit that was stored at 9°C, as the fruit stored at higher temperatures (14°C) was too bad to ripen. Commercially transported fruit(both air and sea) showed very little brown discoloration (see Appendices).

3.5 Nutrients

Mango fruit was sampled to test for nutrients (N, Ca and K) in the fruit flesh (Table 2).

Table 2: Nutrient content of sampled mango fruit for N, Ca and K

	N [%]	Ca [mg/100g]	K [mg/100g]
Brown	0.1	17.8	195
	0.1	27	186
Reference	<0.05	21	185
	<0.05	22	155

No significant differences were observed between these nutrients in brown and reference tissues.

4 Discussion

4.1 Initial firmness

The fruit originated from Peru and was harvested in a low and high risk period for brown discoloration. The experiment was set up to test if maturity of the fruit has a relation with brown discoloration of the fruit flesh. Therefore, initial firmness of the fruit was measured at arrival in the Netherlands since no such measurement device was available in Peru. This was sub-optimal, as the fruit already had a transport history and had lost some of its original initial firmness. Measuring initial firmness should preferably be done directly after harvest in country of origin.

4.2 Acoustic firmness sensor

Measuring firmness with the AWETA acoustic firmness sensor (AFS) is a good method for measuring firmness non-destructively. However the correlation between the AFS and the actual firmness of the fruit is not 100%. The correlation is of such a measurement has not been tested in this experiment. The effect is that there is already variation in the read outs of the AFS measurement. Combined with the contributing biological variation in internal maturity, the correlation between initial acoustic firmness readings in the Netherlands only explains 45% of the variation in internal firmness.

4.3 Temperature

The fruit shipped to the Netherlands with air freight had very limited temperature control. The fruit was shipped at ripening temperatures (20 to 25°C) for approximately 6 days. This has an effect on fruit development and therefore on the comparison of the simulated transport and the actual sea shipment.

In the simulated storage of 14°C the cold room malfunctioned for 12 hours. During this period the temperature slowly dropped to 0°C. Visual inspection showed no direct damage on the fruit, but it is unclear how this affected the overall outcome of the experiment.

4.4 Nutrient analysis

The fruit nutrient analysis is based on a small sample of 4 fruits.

5 Conclusions

For mango one of the problems limiting shelf life is brown discoloration of the fruit flesh after cutting. The following hypothesis were tested in this experiment:

1. Brown discoloration of the fruit flesh depends on time in the season (early / late):
   Late harvested mango fruits (April) show more brown discoloration the early harvested mango fruit (March). Determining the exact turning point was not the objective of this experiment. However this can be tested in the monitoring programme in GreenCHAINge.
2. Brown discoloration is caused by low storage temperature (chilling injury):
   In the April experiment, a higher simulated transport temperature of 14°C to prevent chilling injury caused significantly more internal browning than the simulated transport temperature of 9°C. In the March experiment, no brown discoloration was observed in the simulated transport temperature of 9°C nor in the 14°C. Therefore it is unlikely that chilling injury causes brown discoloration.
3. Brown discoloration is due to an imbalance in nutrients
   No significant differences in small scale analysis were found to support this hypothesis.
4. Large fruit have more problems with brown discoloration than smaller fruit
   Larger mango fruits (S4) showed significantly less browning than the smaller sized (S6) fruits.

These experiments contribute to the larger overall GreenCHAINge research questions:

I. How can initial quality, shelf life and quality be measured and predicted?
   Brown discoloration of the mango fruit flesh is correlated with the internal maturity stage. The more mature the fruit is, the more issues can be found with regard to brown discoloration. The internal maturity status is usually assessed by cutting the fruit in half and evaluating the internal color of the fruit flesh. However this is a destructive measurement. Acoustic firmness was also measured before cutting as a non-destructive measure for firmness. Fruit that was harvested later in season had no external signs of further development, and by hand, all fruits felt firm. The firmness readings with the acoustic sensor revealed that in late season (April) the fruit was initially already softer. The acoustic firmness correlates with the internal maturity stage. In addition, the initial firmness reading corresponds for 45% with the end maturity stage (depending on storage temperature). The maturity stage as estimated by the supplier in M2 and M3 classifications had no significant relation with internal maturity stage nor with brown discoloration. Therefore, acoustic firmness measurements are a first step towards a better classification of mango fruit.

II. What is the influence of environmental conditions (e.g. temperature and humidity) and handling on the quality and shelf life?

The maturation of mango fruit is strongly depended on temperature. The higher the transport or storage temperature, the more the fruit will mature.

III. How can, by understanding specific product-related problems, quality and shelf life be improved?

Classify mango in different categories of initial firmness.

Shipping early and late harvested mango's at the same transport temperature may result in overly mature fruit, with more brown discoloration problems.

5.1 Practical implications

For cutting mango as a fresh packed convenient food a certain maturity is preferred, because of taste, texture and firmness. However, more mature fruit has more issues with respect to brown discoloration. The right balance between the two should be found for the optimal solution.

Acknowledgements

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Appendices

Simulation 14°C – no ripening

Picture 2: External and internal visuals of mango fruit stored at 14°C before ripening for size 4 and 6 and maturity stage 2 and 3

Simulation 9°C – no ripening

Picture 3: External and internal visuals of mango fruit stored at 9°C before ripening for size 4 and 6 and maturity stage 2 and 3

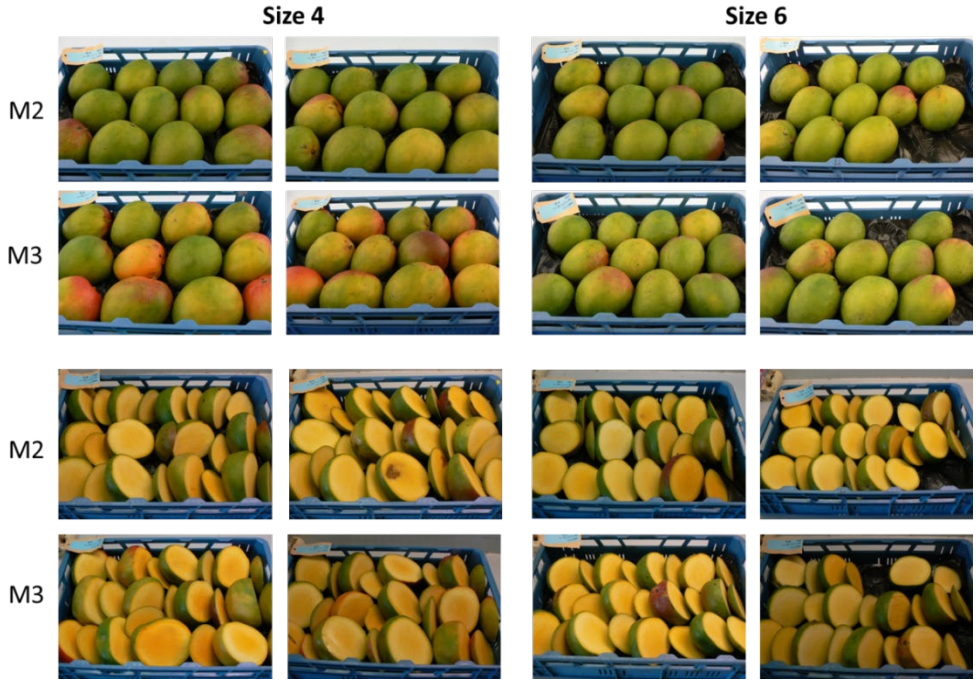
Simulation 9°C – after ripening

Picture 4: External and internal visuals of mango fruit stored at 9°C after ripening for size 4 and 6 and maturity stage 2 and 3

Sea transport – no ripening

Picture 5: External and internal visuals of mango fruit sea freighted before ripening for size 4 and 6 and maturity stage 2 and 3

Sea transport – after ripening



Picture 6: External and internal visuals of mango fruit sea freighted after ripening for size 4 and 6 and maturity stage 2 and 3