DP5 – Blueberries Chain

Summary slides all project

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DP5 Blueberries Chain: Summary project slides

Report 2455, Final

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Fresh on Demand

This project was funded by the TKI Horticulture and Starting Materials foundation (in Dutch "stichting TKI Tuinbouw en Uitgangsmaterialen") of the Dutch Ministry of Economic Affairs and Ministry of Agriculture, Nature and Food Quality (TU18098 and TU18022).

Summary

How to objectively assess textural quality aspects of a blueberry batch?
This was the objective of this sub-project within the four-years umbrella project Fresh on Demand. Textural quality aspects were defined as firmness, mealiness and internal breakdown.

The research has delivered:

- an assessment method to measure the firmness of blueberries based on Hyperspectral Imaging (HSI), non-destructive and very fast (slide 49). The HSI model was built based on the Fmax values obtained from FTA (Fruit Texture Analyser) measurements.

- accuracy and robustness of the assessment method validated with blueberries from different cultivars, different growers and originating from different distribution chains (slide 83 and 85).

- sample size defined: how many blueberries in a batch should be measured to achieve the necessary accuracy. 100 berries per batch seem to be enough.

Accuracy Fmax defined: ±0.07 kg; Root Mean Square Error (RMSEP) of the HIS assessment method, ie the prediction error, is 0.036 Kg. The prediction error of the HSI assessment method is lower than the required accuracy, meaning that the HIS performance is high and very suitable to measure blueberries batches.

- insight in the performance of hand-held firmness devices (Baxlo and Turoni): The performance of the Baxlo was different throughout the project. Based on this research it can be concluded that special attention is needed for the deterioration over time and maintenance of the device. The Turoni seems to be a good alternative for the Baxlo.

For the development of the HIS assessment method the berries were placed on a specific position in blue plates. For an industrial application this is however time consuming. We have evaluated if rolling the berries on a surface would be a feasible way of measuring the berries. This seems to be promising. (slide 86-88).

Future view of HSI non-destructive firmness assessment:
- Integration of the model in the hyperspectral cabinet (now the model runs in separate software/computer)
  - Automatically identify each berry image
  - Software to run model and provide average + variance each batch
- Maintenance will be needed time to time
- Upgrade to other cultivars

Fresh on demand

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Content

- Kick-off project
- First year– Focus mealiness (2019)
- Second year- Focus non-destructive texture method (2020)
- Third year– Improve texture method; Develop HSI assessment method (2021)
- Fourth year – Validation & company implementation (2022)
- Final project conclusions

Content

- **Kick-off project**
- First year– Focus mealiness (2019)
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Project objective

Increase the quality of blueberries and minimal losses in the production chain

Workshop Quality

Objective of the workshop:

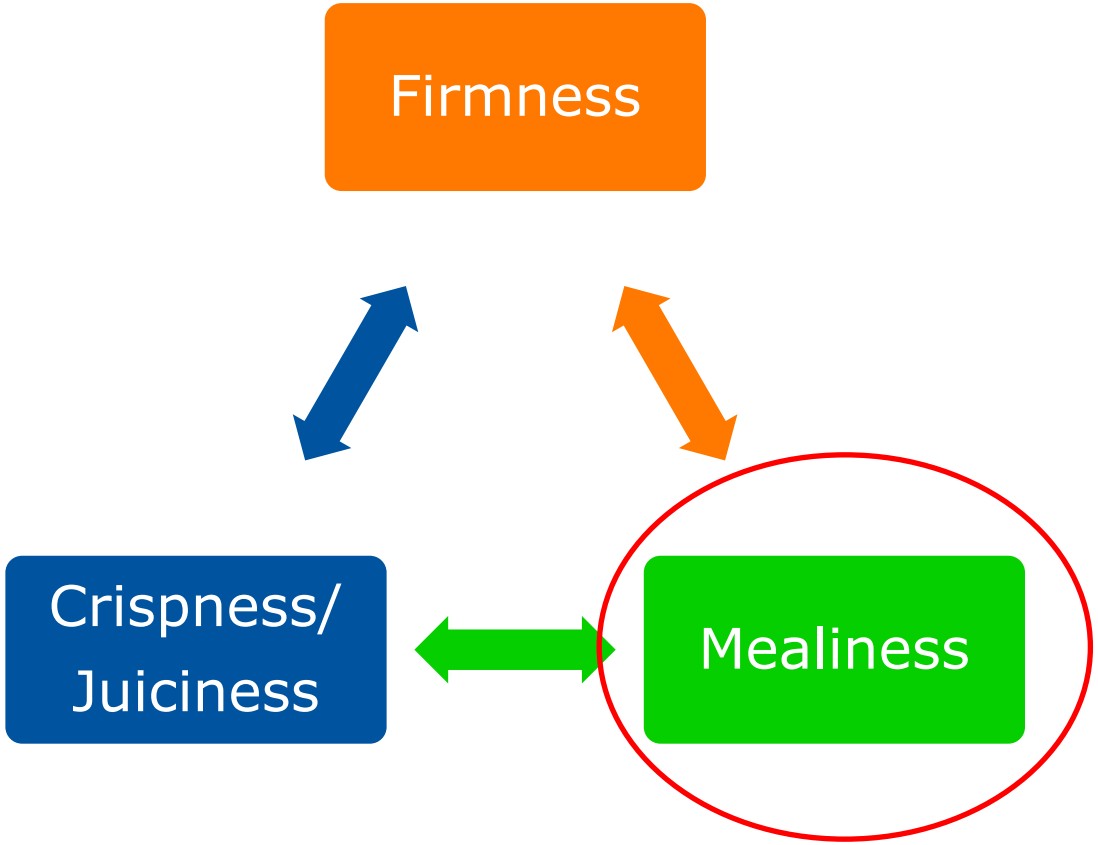
- Exchange info and views
- Make a choice for the project

What is a Quality Blueberry?

- Deep purple-blue colour
- Uniform size & appearance
- Crisp texture & good crunch
- Consistent flavour (aroma and sweetness)
- Good shelf-life
- Free of moulds and rots
- .....

Prioritise!!! Make a choice to focus the research...

Quality – Texture: 3 important aspects



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First project year – Focus Mealiness

- Theoretical background mealiness is known based on:
  - Scan Electron Microscopy (SEM) analysis
  - Pectin analysis
  - Cell wall enzyme activities (polygalacturonase, pectin methyl esterase, β-galactosidase and α-arabinofuranosidase)

- But what are the current assessment methods?

First project year – Focus Mealiness

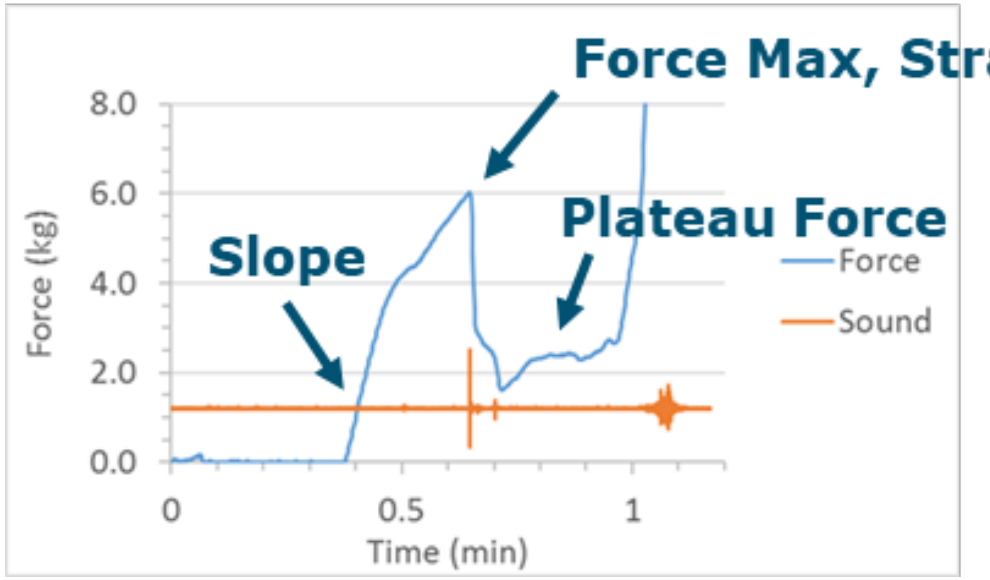
- Explore sources of current knowledge/experience:

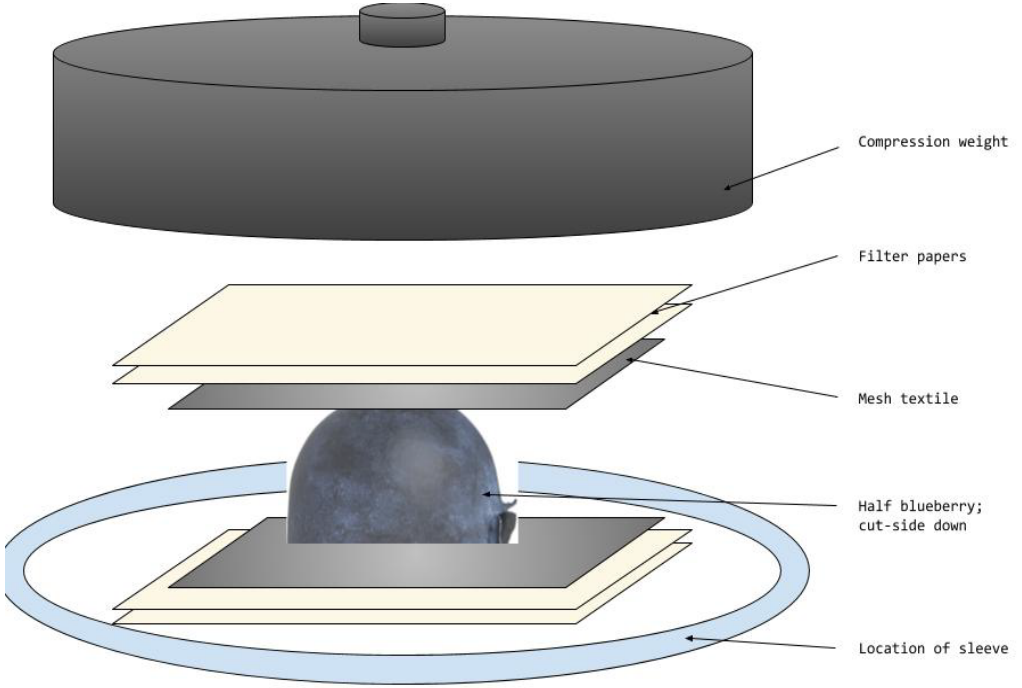
1. Results of literature search:
    - Juiciness most relevant instrumental method
    - Force or Young's module low correlations
    - Sensorial evaluation most reliable but not instrumental

2. Brainstorm with other researchers

First project year – Focus Mealiness

- Assessment methods tested + sensorial evaluation:
  - Amount juice (juiciness)
  - Sound (number pulses + total intensity)
  - Force plateau (parameter from texture analyser)
  - Under Water Weight





First project year–Focus Mealiness: Tests+conclusions

- Test 1 (600 individual berries):
  - Texture analyzer: Force plateau + sound (intensity) correlate on average but not on individual berry
  - Weight, size or moisture content are not related to mealiness

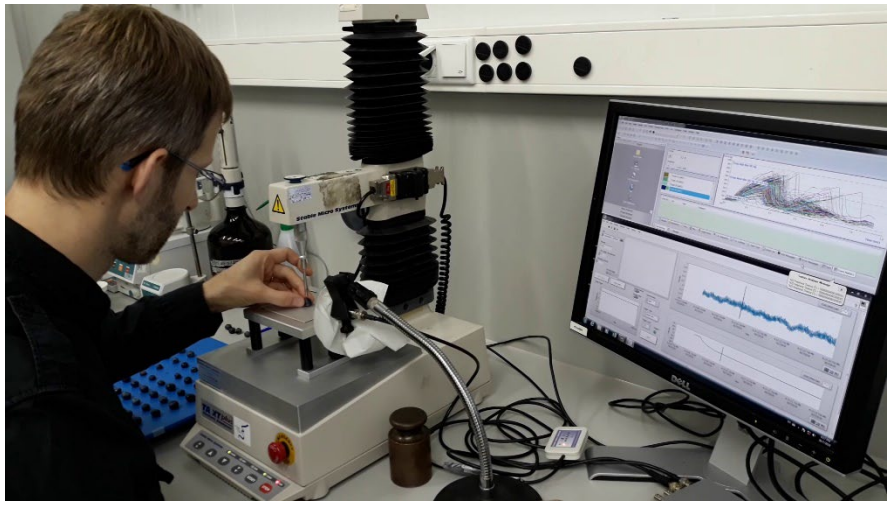
- Test 2:
  - Correlation juiciness - sensorial assessment is limited (r= 0.6)
  - Impact of mealiness on the juiciness of the blueberry differs per batch/cultivar

Test 1 - Workflow

1. Plating & Weighing

2. Colour & Size

3. NIR



4. Firmness & Sound

5. Mealiness & Dry matter
[no picture]

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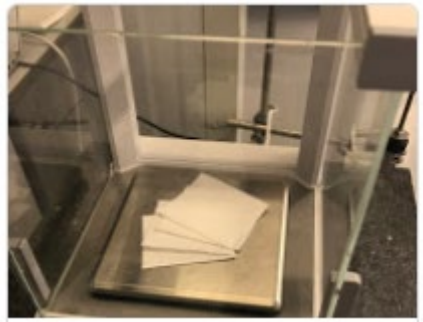
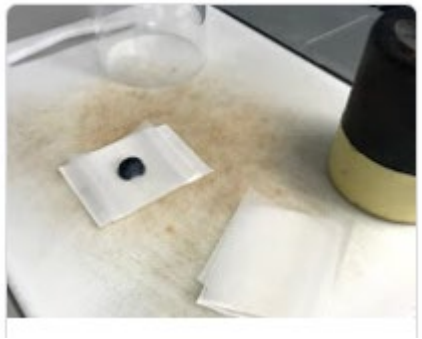
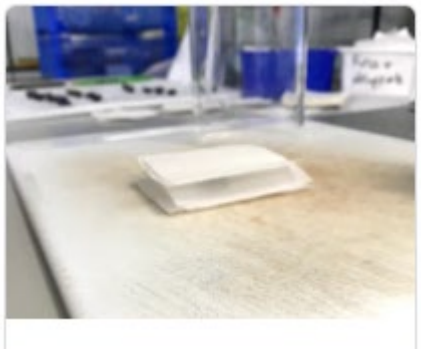
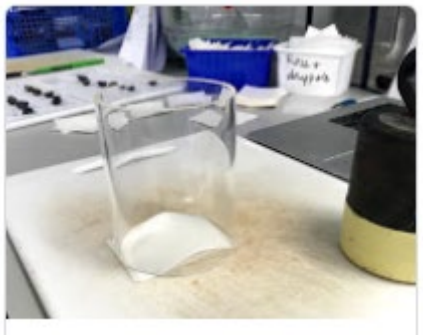
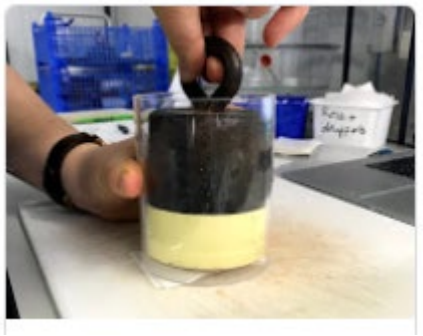
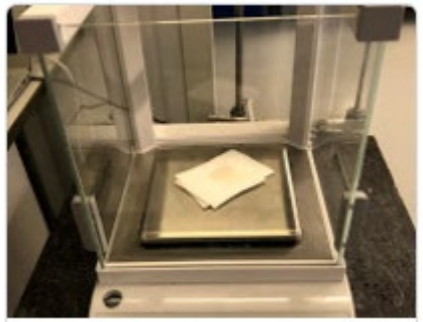
Test 2 - Juiciness assessement



First project year – Focus Mealiness: Conclusions

- Juiciness is destructive + labour intensive + cultivar dependent -> not suitable (a relationship per cultivar/group of cultivars would be needed)

- Relationship instrumental methods and sensorial score mealiness is not high enough to use as reference method

Change strategy!

Note: Angelo Castro is PhD in Leuven and works on the topic

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Fresh on demand

Objective research project - New strategy

- Development of an assessment method to measure ***texture** of blueberries (as **objective quality monitoring tool**)

- objective assessment (instrumental)
- focus on soft berries
- give firmness level value for a batch including variation
- applicable in company operations/industry
- it should be fast enough
- the assessment method may be further developed in the future
- *may be destructive*

*Texture = Firmness + Mealiness + Internal breakdown

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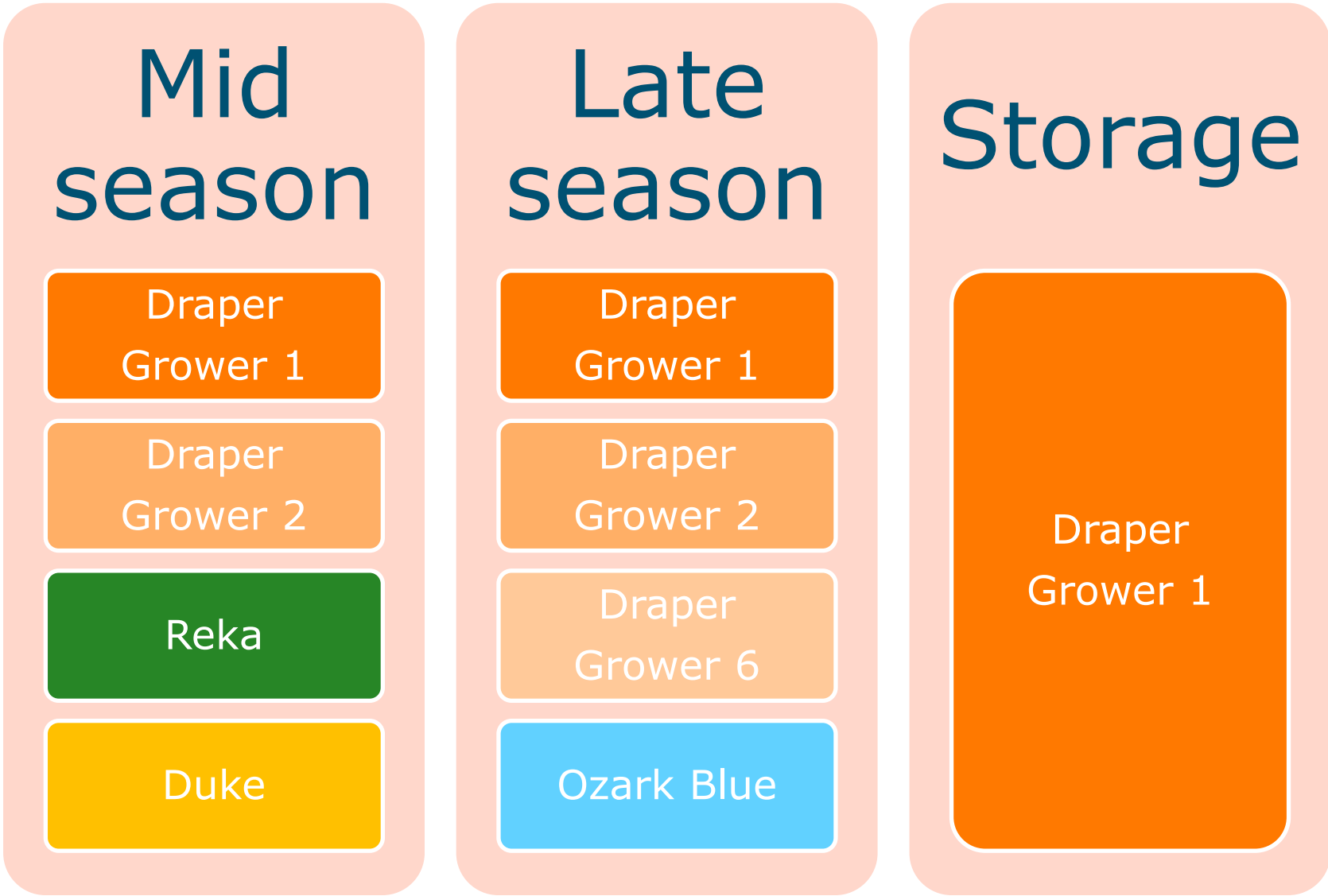
2nd project year – New strategy

***Texture = Firmness + Mealiness + Internal breakdown**

- Focus on non-destructive method particularly suitable for soft berries
- Explore NIR -> wide spectral range (350-2500 nm) to cover different features, for instance including soluble pectin at 900-1700 nm
- Evaluate reference methods
- Explore other options: Turoni (other measurement principle) + Under Water Weight
- Sensorial evaluation requires fine tuning

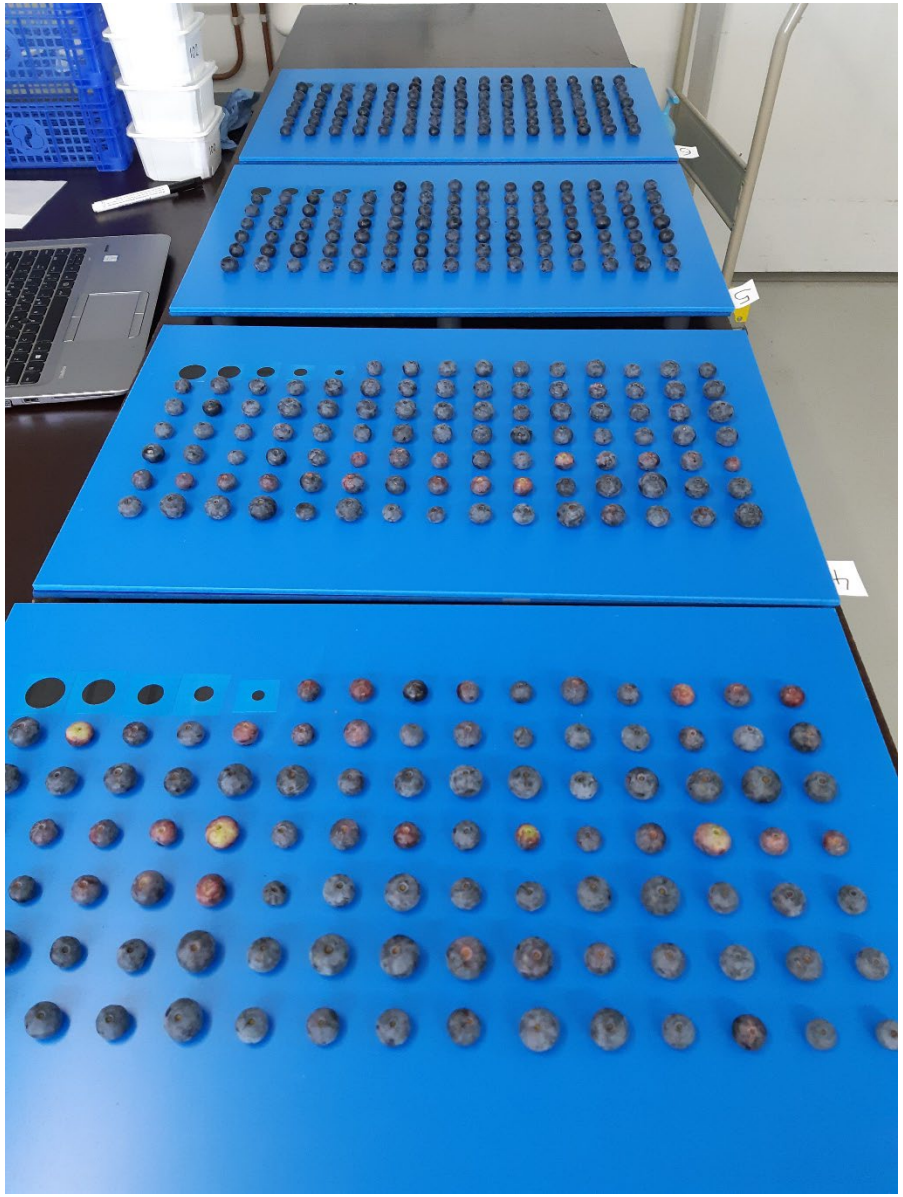
2nd project year – One spot NIR (350-2500 nm)



Total 1600 berries were measured

Test set up: number of samples and berries

- 5 punnets per batch
- 20 berries per punnet



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2nd project year - measurements

Colour

NIR

Texture 1

Texture 2

Texture 3

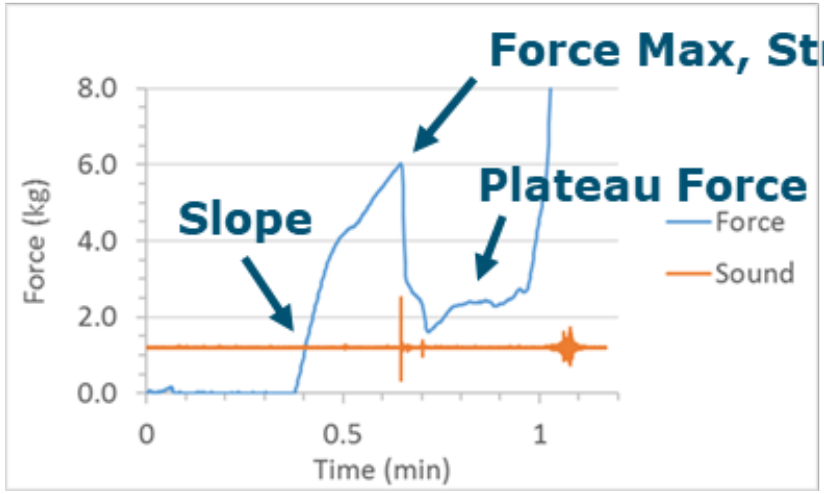
Sensorial assessment

Under water weight

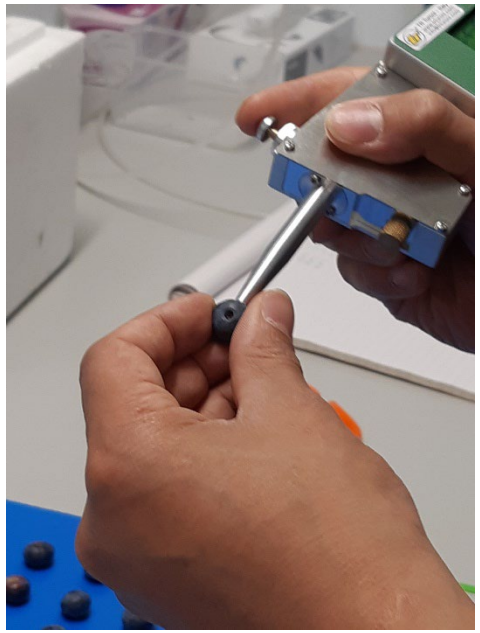
ASD Labspec 350-2500 nm

Methods to quantify texture

- FTA: Full texture measurement comprising several parameters that may be related to different texture aspects; Objective



- Turoni: measures probe deceleration after impact. Also objective



- Handheld firmness device (Baxlo; used by The Greenery): Same principle as FTA but faster and less controlled

- Under water weight: not the first choice this is out-of-box method

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2nd year - Reference & alternative methods

Correlations (r) with sensorial assessment (on punnet level/average punnet)

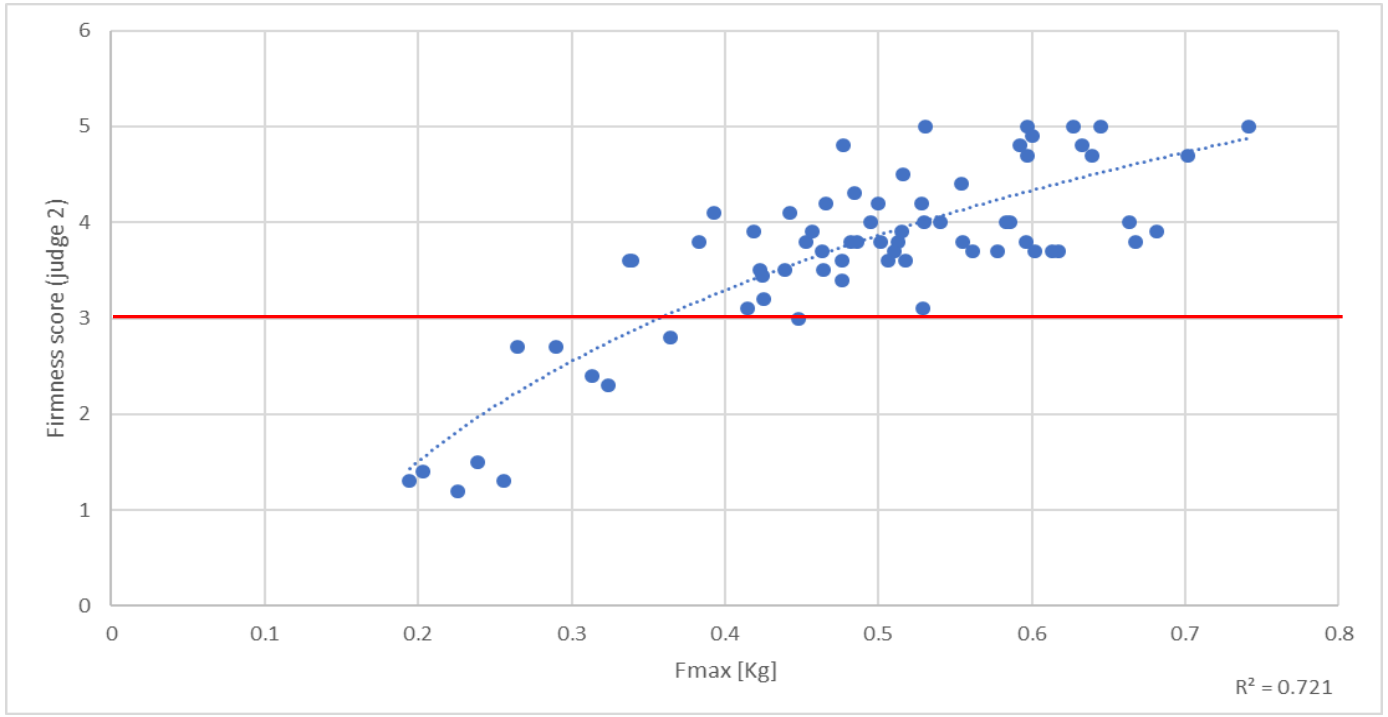
Method	Firmness score	Mealiness score	Internal Breakdown score
Fmax (kg)	0.81	-0.90	-0.87
Young modulus (kg/% strain)	0.73	-0.81	-0.77
Strain at max (%)	0.36	-0.49	-0.33
Plateau Force (kg) (=flesh firmness)	0.72	-0.80	-0.84
Turoni	0.42	-0.64	-0.73
Baxlo (N)	0.59	-0.61	-0.79
UWW (g/cm3)	-0.81	0.77	0.87

Without Reka!*

High correlation due to Reka!*

**data set with Reka shows higher correlations because this cultivar had clearly softer berries. Reka was not measured with Turoni.*

Relationship FTA (Fmax) + Firmness (only judge 2)

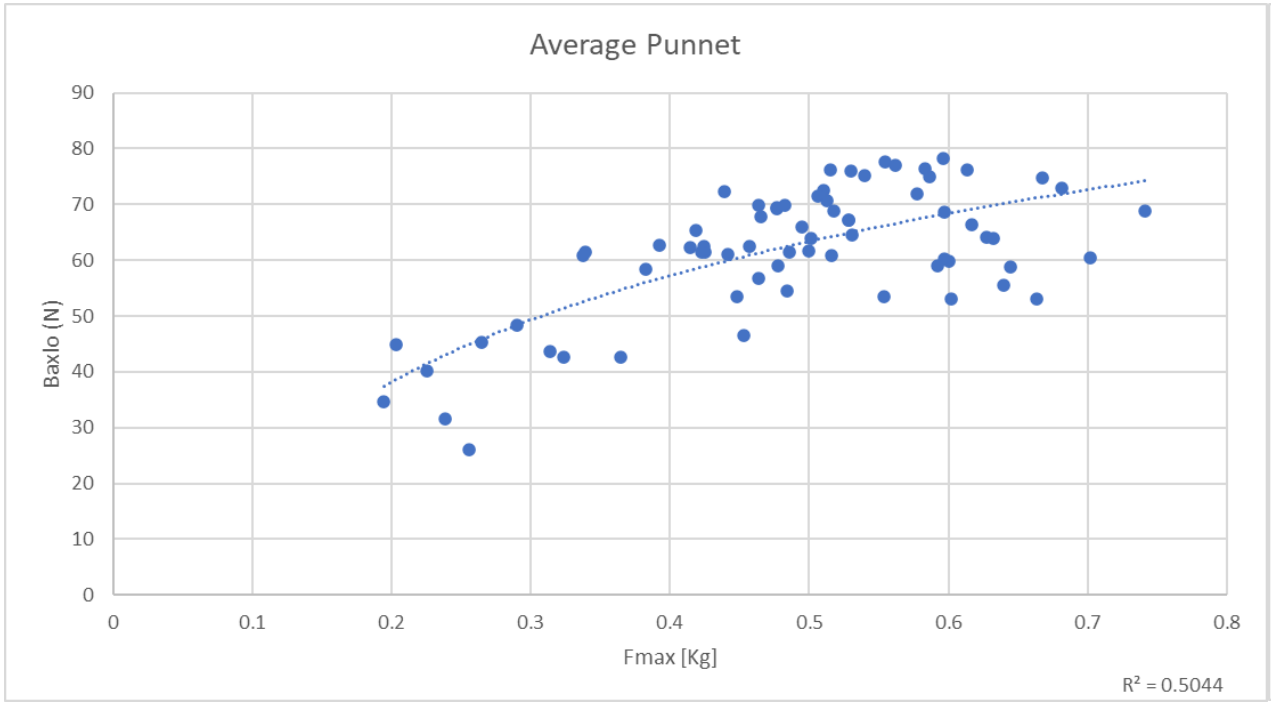


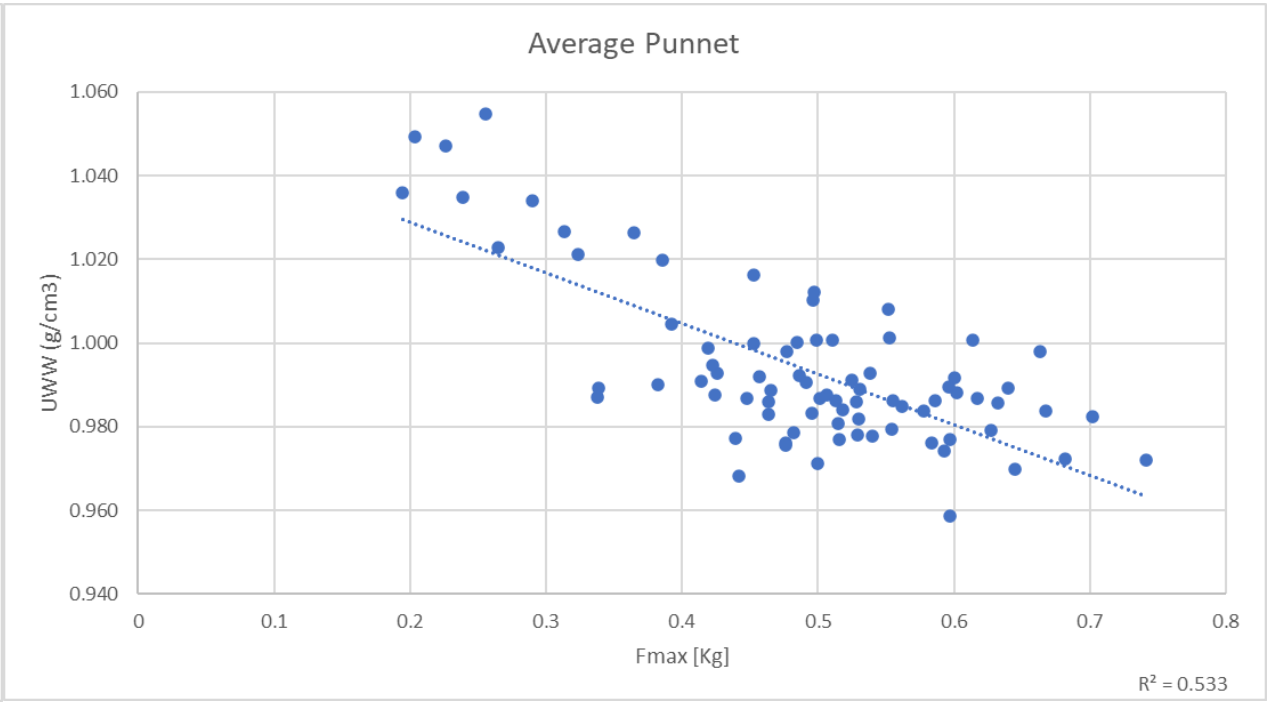
Firmness
1- very soft
2- soft
3- just hard enough (acceptance limit)
4- hard
5- optimal hard

- Punnet average
- Soft berries: too few samples
- Correlation quite good: R^2=0.72 (logarithmic function)

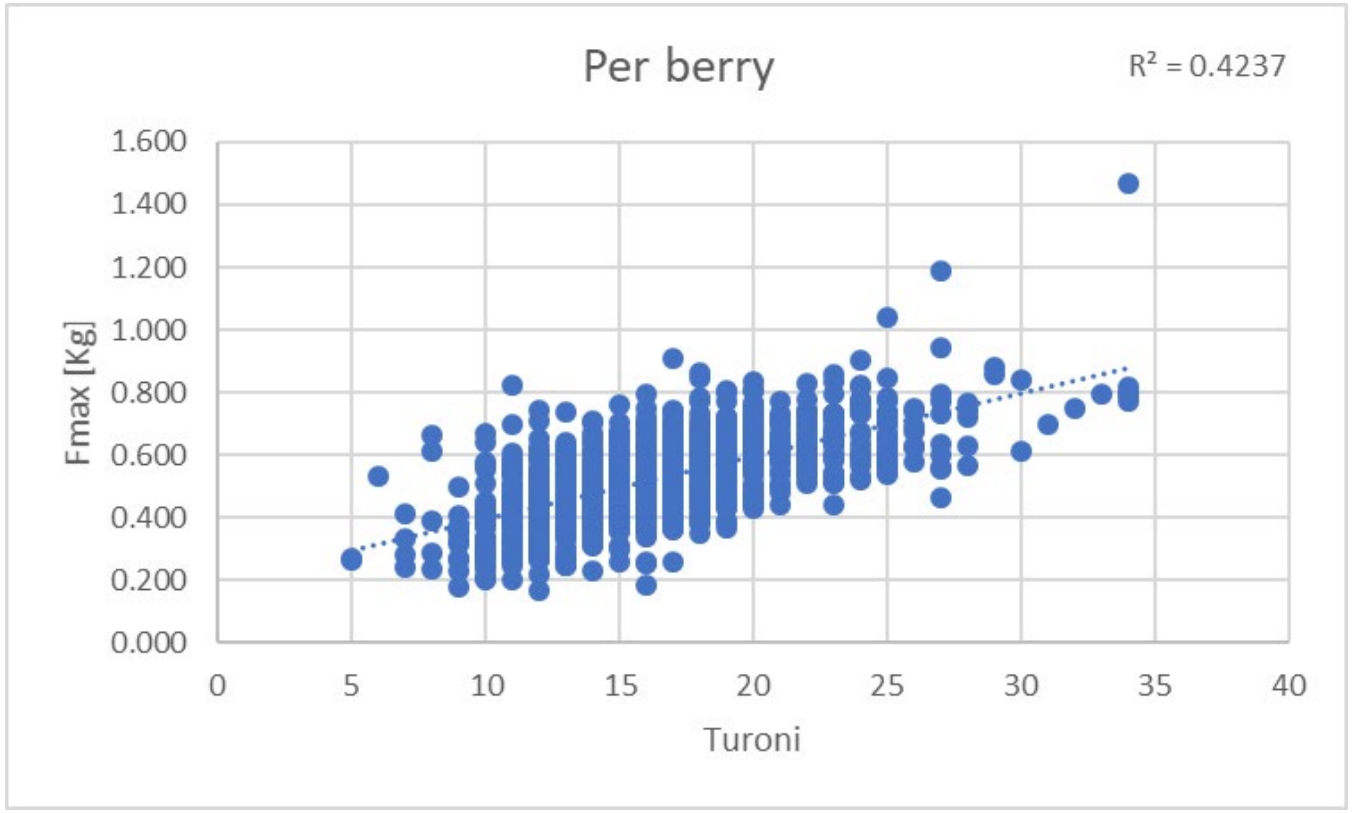
2nd year – Reference & alternative methods

Punnet average, including Reka samples





2nd year – Reference & alternative methods



Correlation per berry, without Reka but still 1180 berries

So result Turoni is rather reasonable

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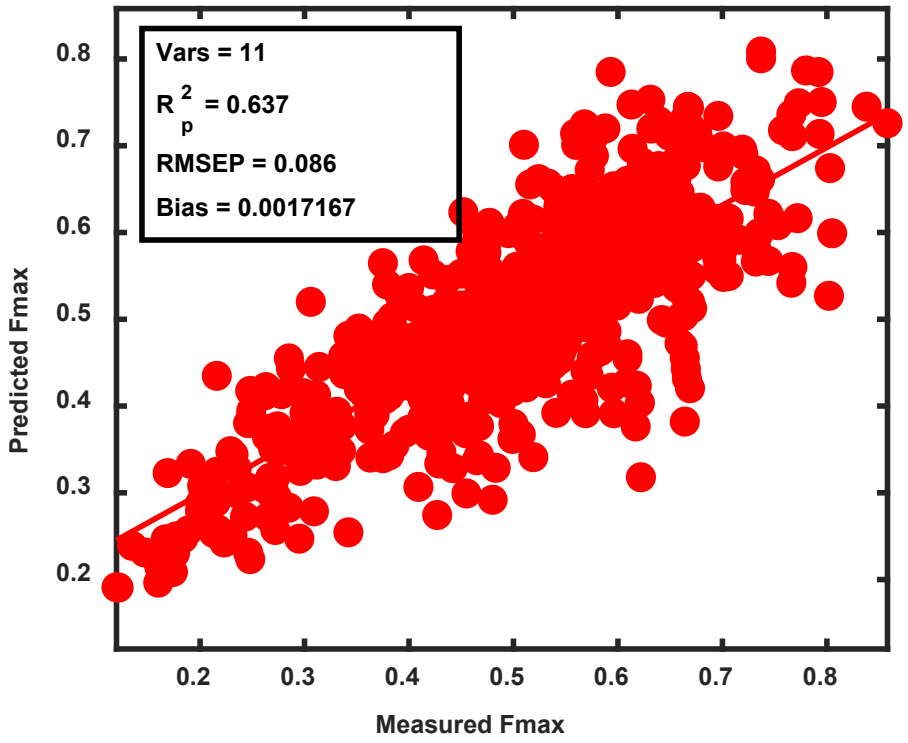
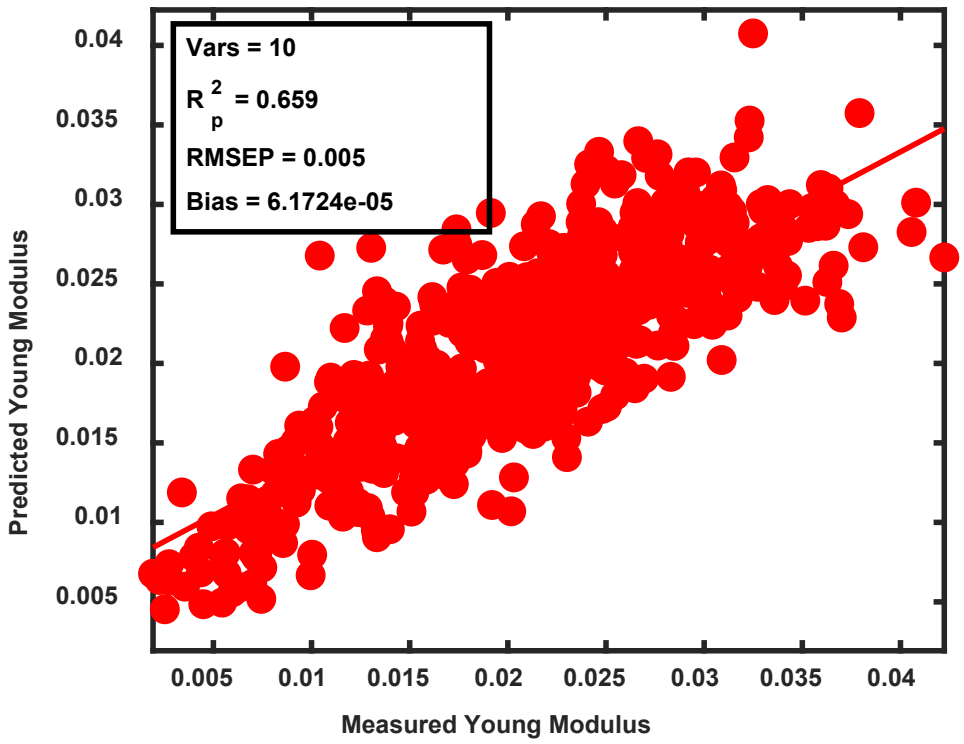
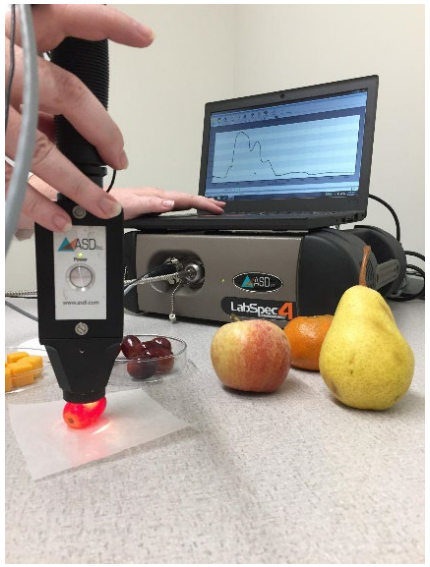
NIR Model for Fmax and Young modulus





Varsel : **890, 914,977,989, 1057, 1146, 1159, 1369, 1373, 1723, 1780**

Varsel : **885, 928, 937, 1004, 1009, 1059, 1116, 1312, 1706, 1781**



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Deep learning models (non-linear)

Explore non-linear models -> does it improves the performance?

Deep learning (non-linear) vs partial least-square (PLS) regression (linear):

	PLS	Deep Learning
Flesh firmness	0.08	0.08
Strain	6.78	7.51
Force Max	1.07	1.07
Young Modulus	0.005	0.007

No significant improvement with Deep Learning hence not to explore further

2nd project year – Conclusions

- FTA correlates better with sensorial firmness than Baxlo, Turoni or Under Water Weight

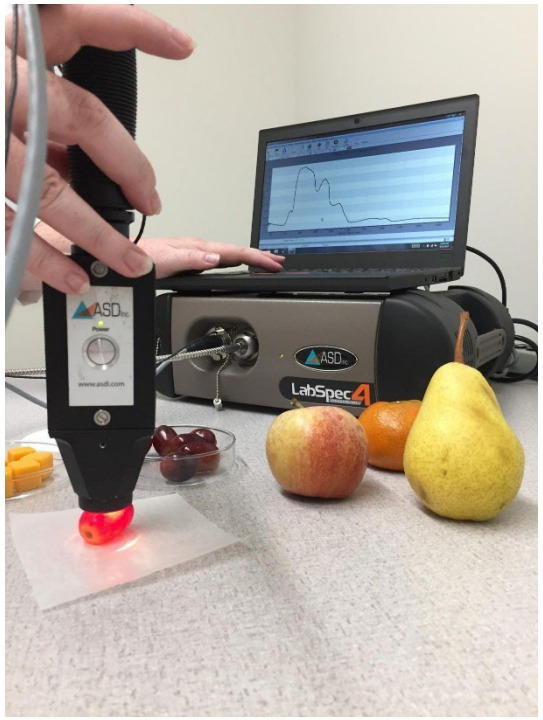
- Performance for Fmax and Young modulus is clearly better than plateau force (= flesh firmness) or strain (at berry level)

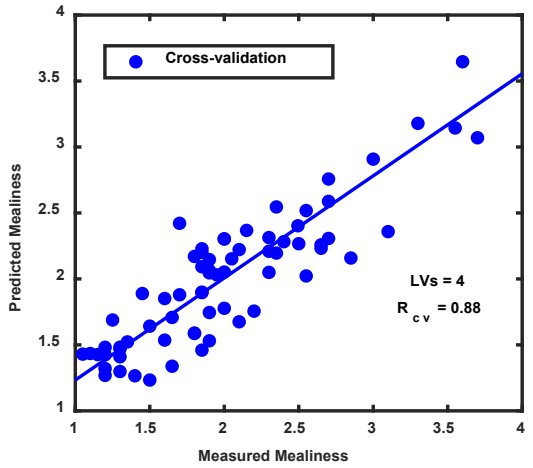
How about the sensorial parameters?

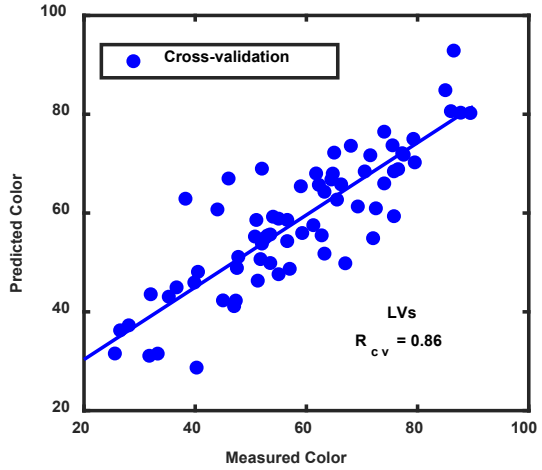
2nd project year - NIR model for sensorial properties

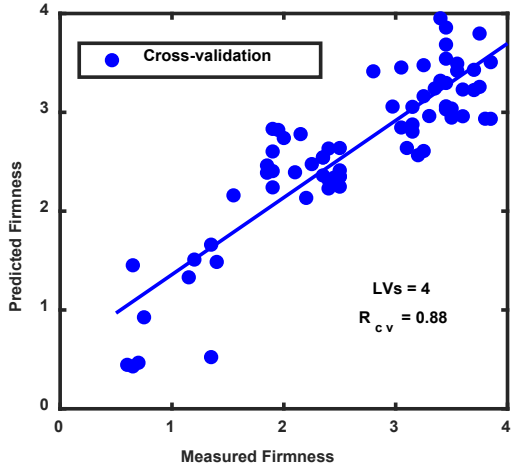
Capability of NIR (400-1000 nm)

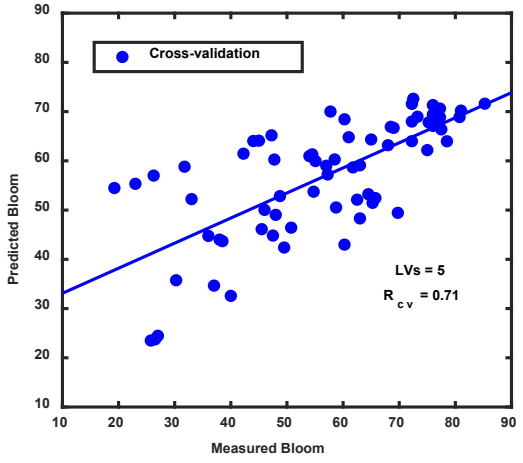
to predict sensory properties:

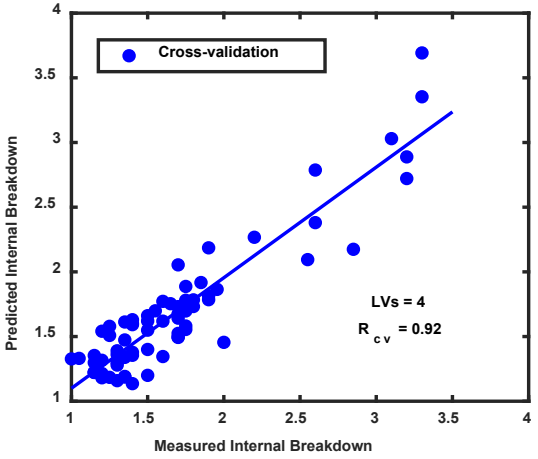












Due to small number of samples it was not possible to use an independent test set; this performance is therefore indicative

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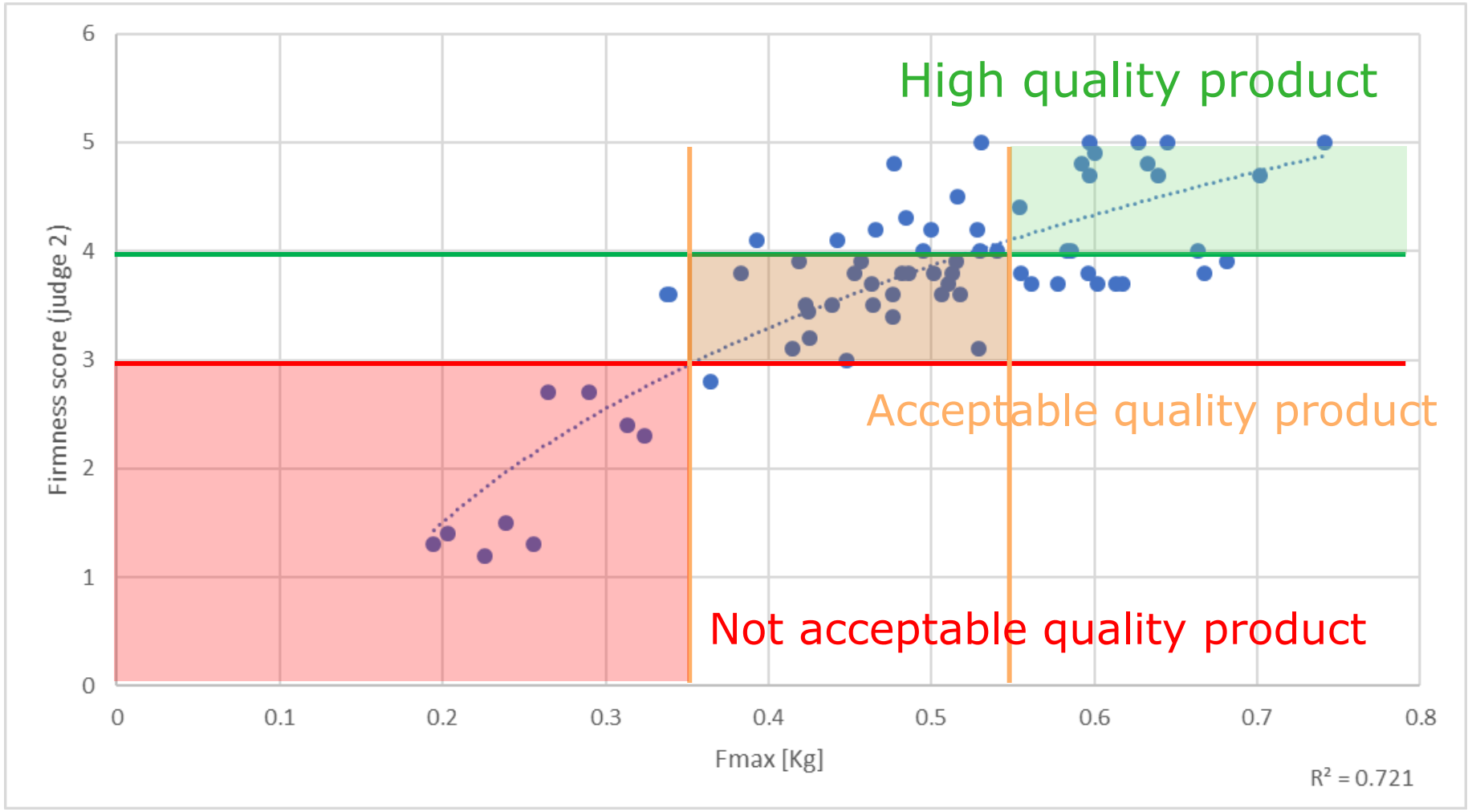
2nd year – Fmax --→ sensorial analysis

Use Fmax to assess firmness product quality and identify high, average and unacceptable batch quality

Acceptance level



Firmness score 3 is considered as the acceptation limit; below the berries are too soft and not commercially acceptable

2nd project year – Conclusions

- Visible/NIR model capable of predict firmness of blueberries (force max and young modulus; performance tested on independent test set.) -> promising!
- FTA much better dan other methods -> reference method
- Turoni seems more reliable than Baxlo
- Firmness score needs better fine tuning; Scores for mealiness and IB rather acceptabel (well done by the judges!)
- Relationship NIR – sensorial parameters to be explored further
- The amount of soft berries was too small

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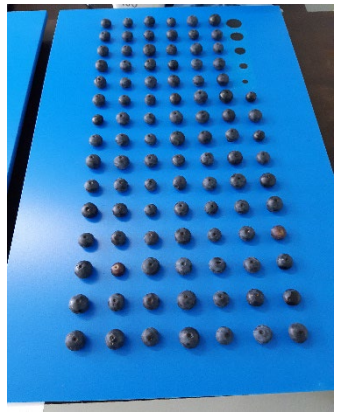
2nd project year – Nice conclusions, but:

1) measuring berries one by one takes a lot of time!
2) one spot-NIR measurement requires some precision
3) instrument is relative expensive....

What are alternatives ?

Can the spectral range be reduced while keeping enough information for the assessment?



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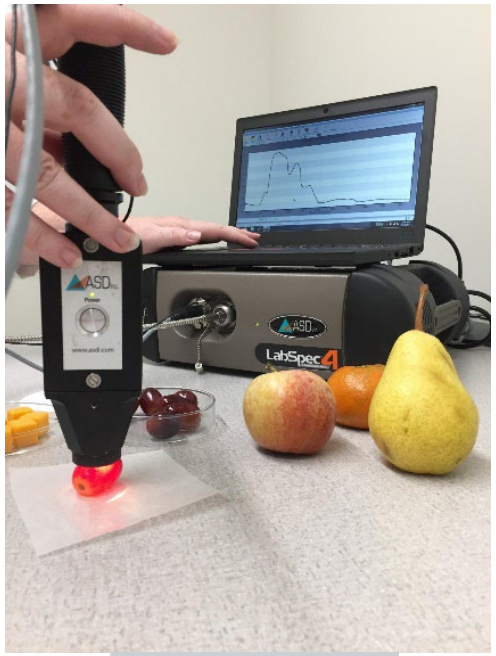
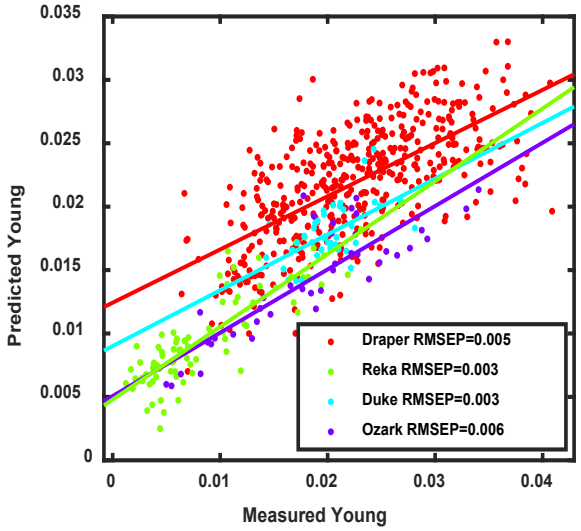
Reduced spectral range model is possible!

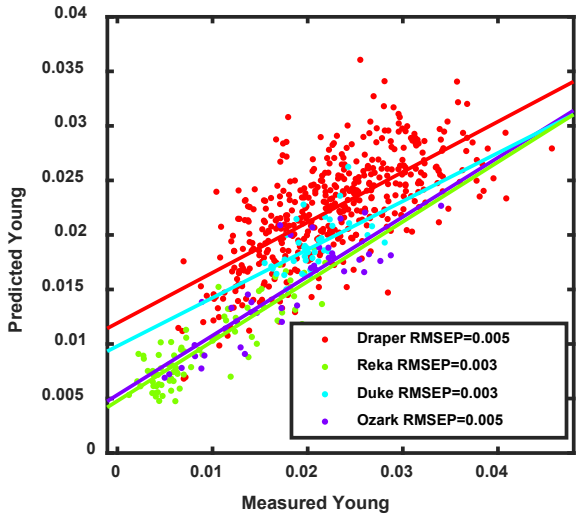


ASD Labspec

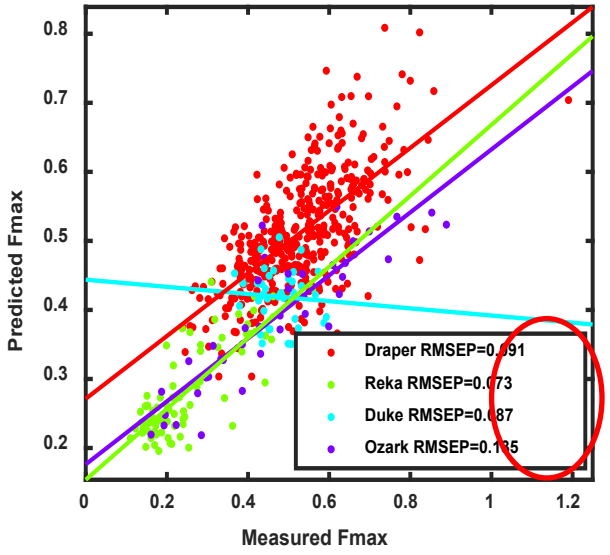
350 – 2500 nm

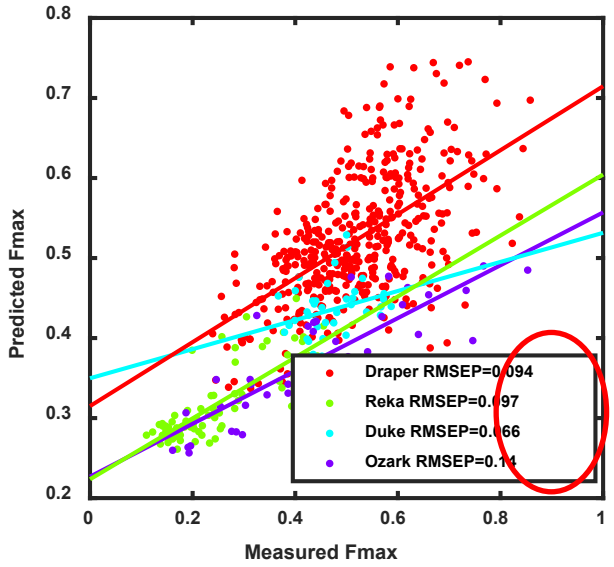
Cost: 50 k





Cost: 7 k





400 – 1000 nm
Cost: 12 k

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3rd project year – Move to hyperspectral (HSI)!

- Wavelength analysis confirms the possibility to apply hyperspectral camera -> less time consuming and lower cost devices
- Cost & performance analysis NIR sensors (together with DP2)
- Search for emerging sensors (bvb THz, ultra-sound probes)
- Firmness score (sensorial evaluation) requires improvement/fine tuning

3rd project year – Move to hyperspectral!

Instrument	Spectral range (nm)	Resolution (nm)	Dimensions (cm)	Price (indication)
DLP NIRScan Nano	900 – 1700	10	7x 6,5 x4,5	K€1,- *(is a component)*
ASD Labspec	350-2500	1 nm	30x30x15	K€40-50
Felix F-750	310 – 1100	8-13	18 x 12 x 4,5	K€7,5
FX10; Hyperspectral*	400 – 1000	5.5	15 x 13 x 7	K€12,-
FX17; Hyperspectral	900 – 1700	8	15 x 13 x 7	K€40
Neospectra Micro	1350 – 2500	16	7 x 5 x 6	K€2,5
OneThird	640 – 1100	10	11 x 65 x 11.5	License service
SCIO	700 – 1100	13	5.5 x 3.6 x 1.5	*K€2,-*

* Optimal choice

PORTABLE HYPERSPECTRAL SETUP AT WAGENINGEN

- A one solution to imaging, model deployment and real time decision making
- Key features:
  - Provides a standardized environment for replicable results
  - Provide easy user interface
  - Real-time model deployment and results interpretation

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3rd project year–Develop Hyperspectral NIR model for firmness

- Measurements at harvest and after 6 weeks of storage (at 1°C, 90% RH) -> effect storage
- 5020 berries were measured (see next slide)
- Measurements after storage:
  - Hyperspectral Imaging (HSI cabinet 400-1000 nm)
  - Firmness (Limited Compression (LC) and Fmax)
  - No Baxlo measurements
  - Sensorial analysis (1260 berries)
- Measurements at harvest:
  - Hyperspectral Imaging (HSI cabinet 400-1000 nm)
  - Firmness (Limited Compression (LC) and Fmax)
  - Turoni

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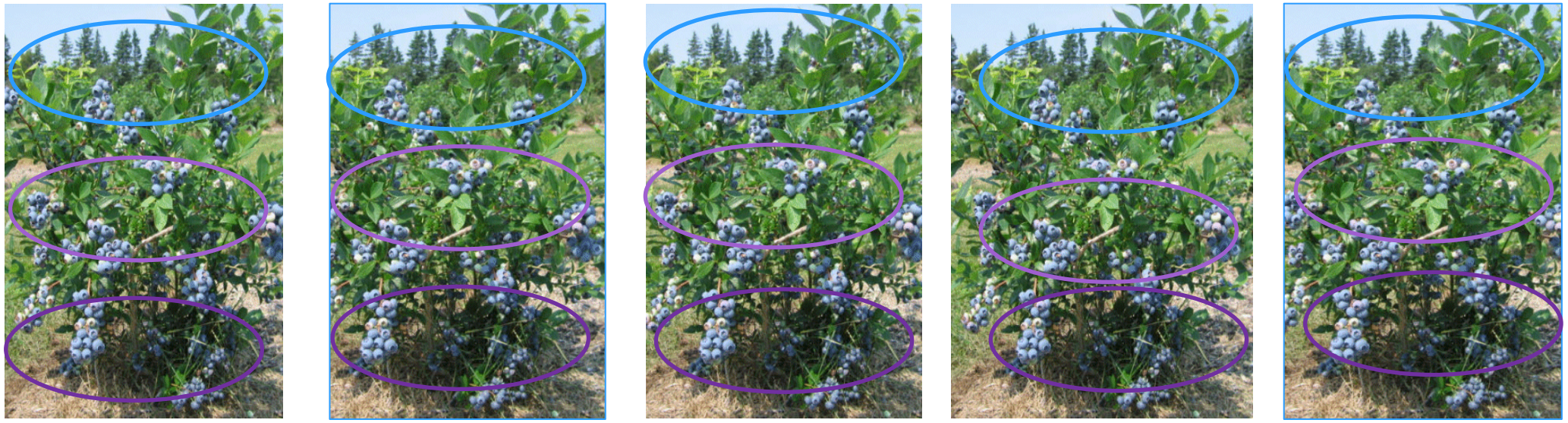
Fresh on demand

3rd project year – Matrix test set up

Berries produced in field selected for these tests (cultivar: Duke)



- ✖ "Less ripe" berries from middle harvest were used for the late harvest -> 6 weeks storage

Ripeness leve	Production moment		
	Early	**Middle**	**Late**
Less ripe	7	7	7 ✖
Optimal*	7	7	7
Ripe	7	7	7

**Optimal= comercial ripe*

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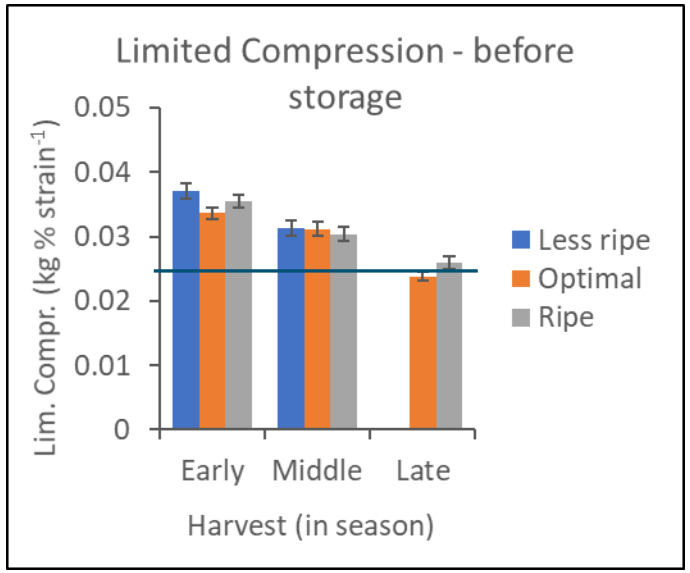
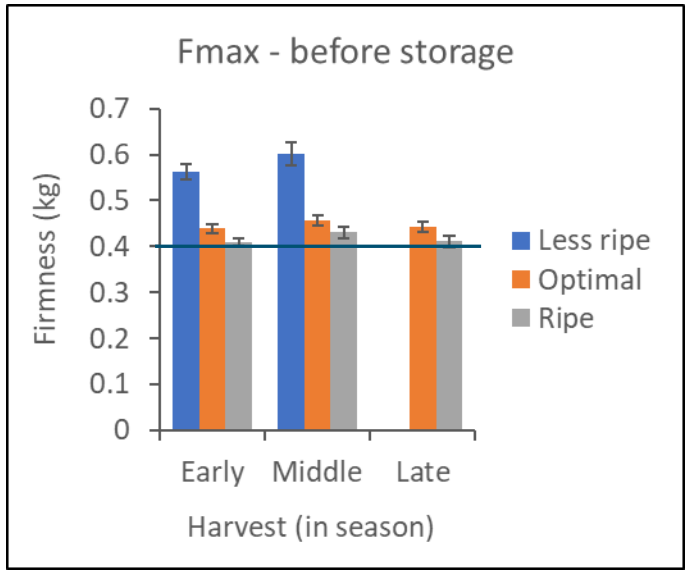
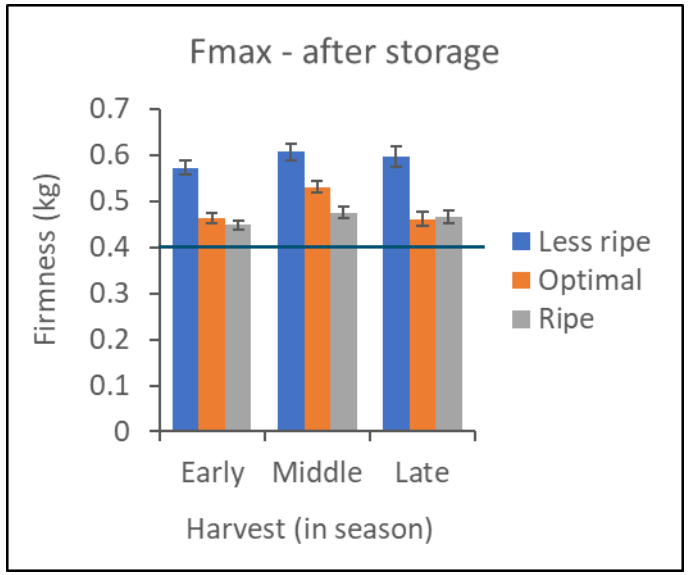
3rd project year – Effect storage

Average of 5 punnets





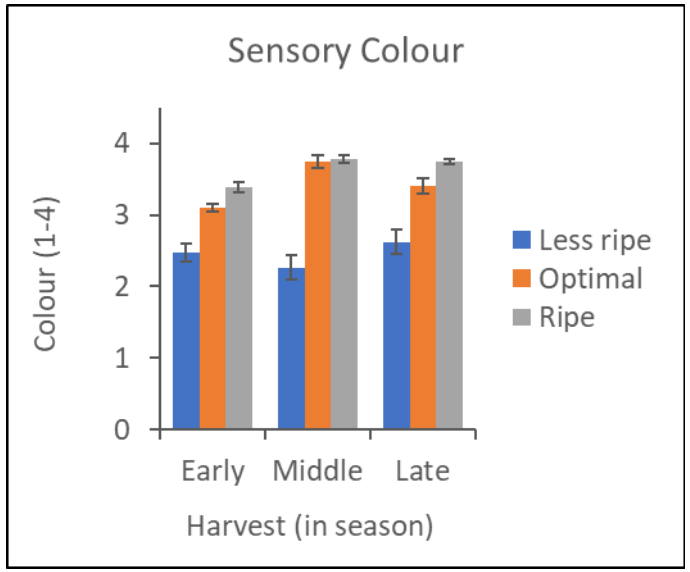


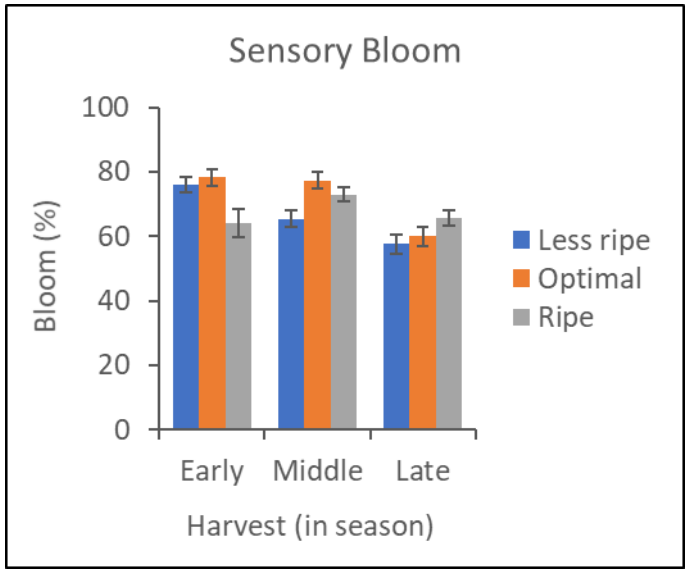
- LC (=limited compression) at harvest decreased with season progression
- Fmax at harvest did not change with season progression
- Berries became slightly more firm during storage

3rd project year - Sensory (colour & bloom)

Sensorial assessment is only done after storage and not directly after harvest = stored samples only

Average of 5 punnets





- Colour was scored higher in more ripe berries, irrespective of season
- Bloom seems inconsistent with harvest or ripeness level

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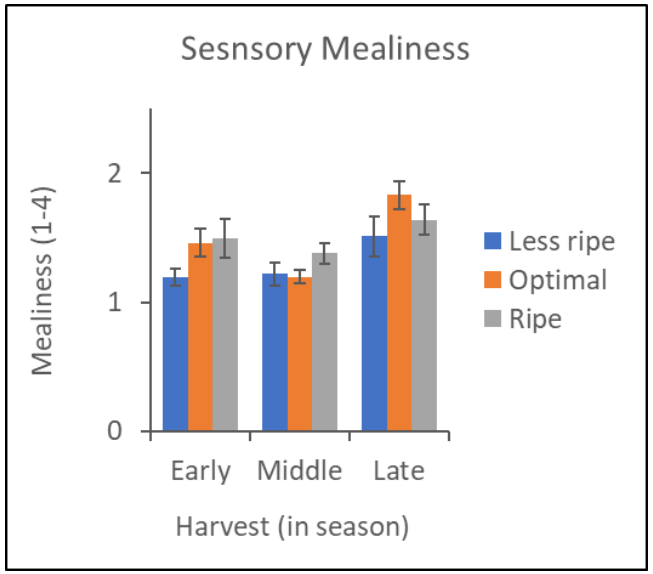
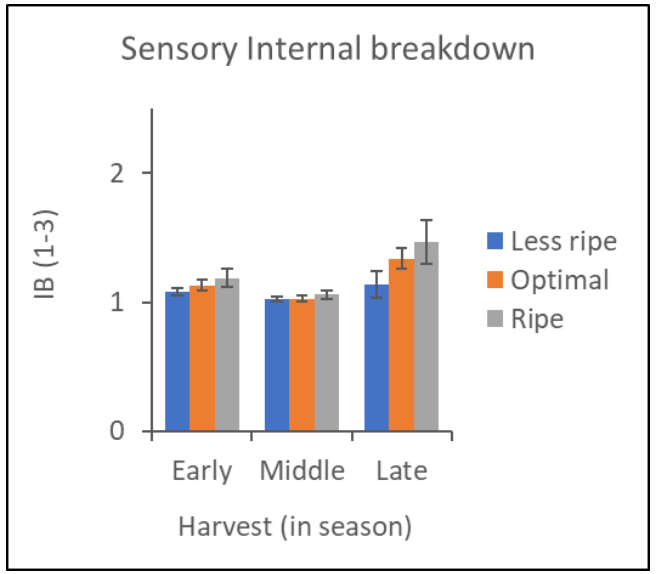
Sensory (mealiness and int. breakdown)

Sensorial assessment of the stored samples only

Average of 5 punnets

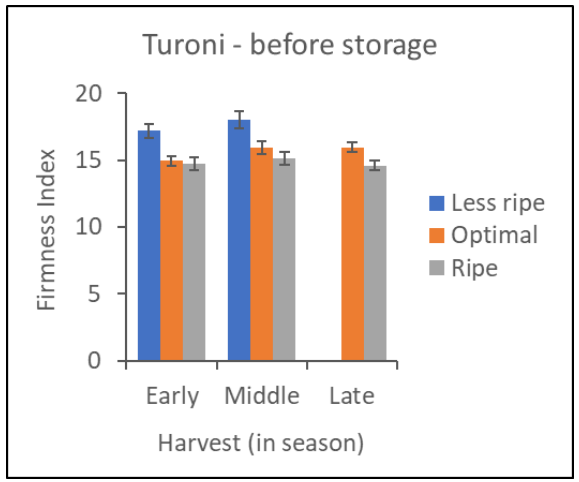


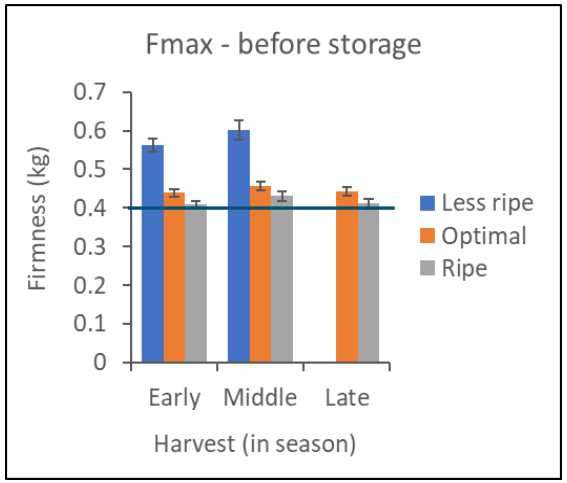


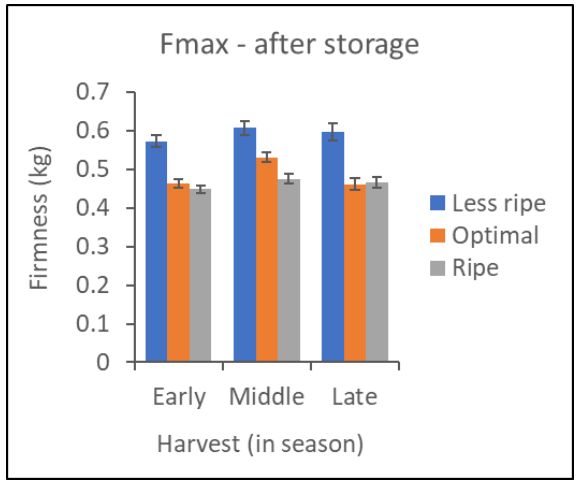
- Mealiness increased with ripeness level and was higher in late season
- Internal breakdown was highest in late season and increased with ripeness level

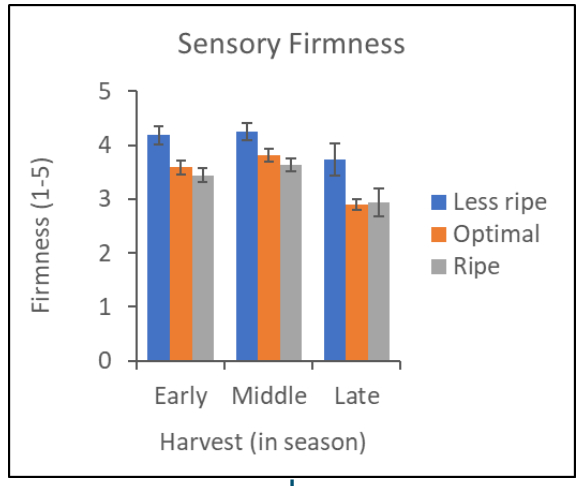
Sensory (firmness) and Fmax

Average of 5 punnets







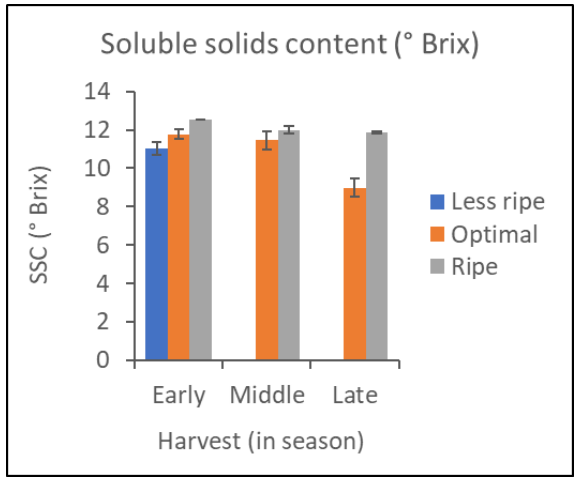


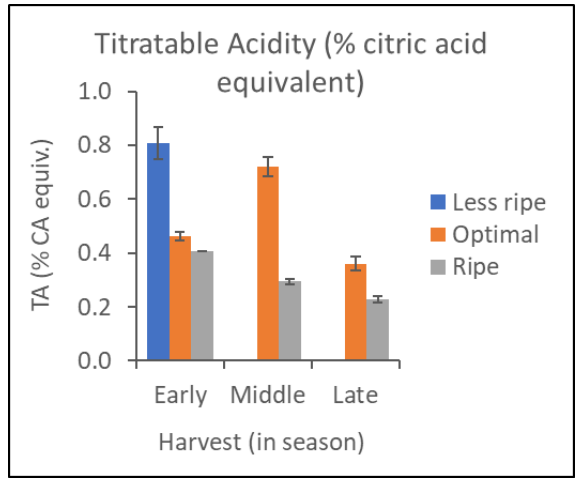
Sensory firmness after storage

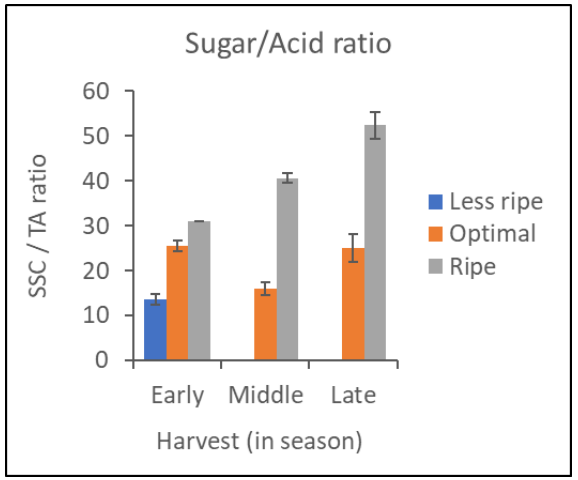
- Sensory firmness measured at the same time as Fmax and Turoni after storage

3rd project year - Soluble Solids Content and Acid

All samples measured at the same time at the end of the test (=after the 6 weeks storage of the late harvest samples)





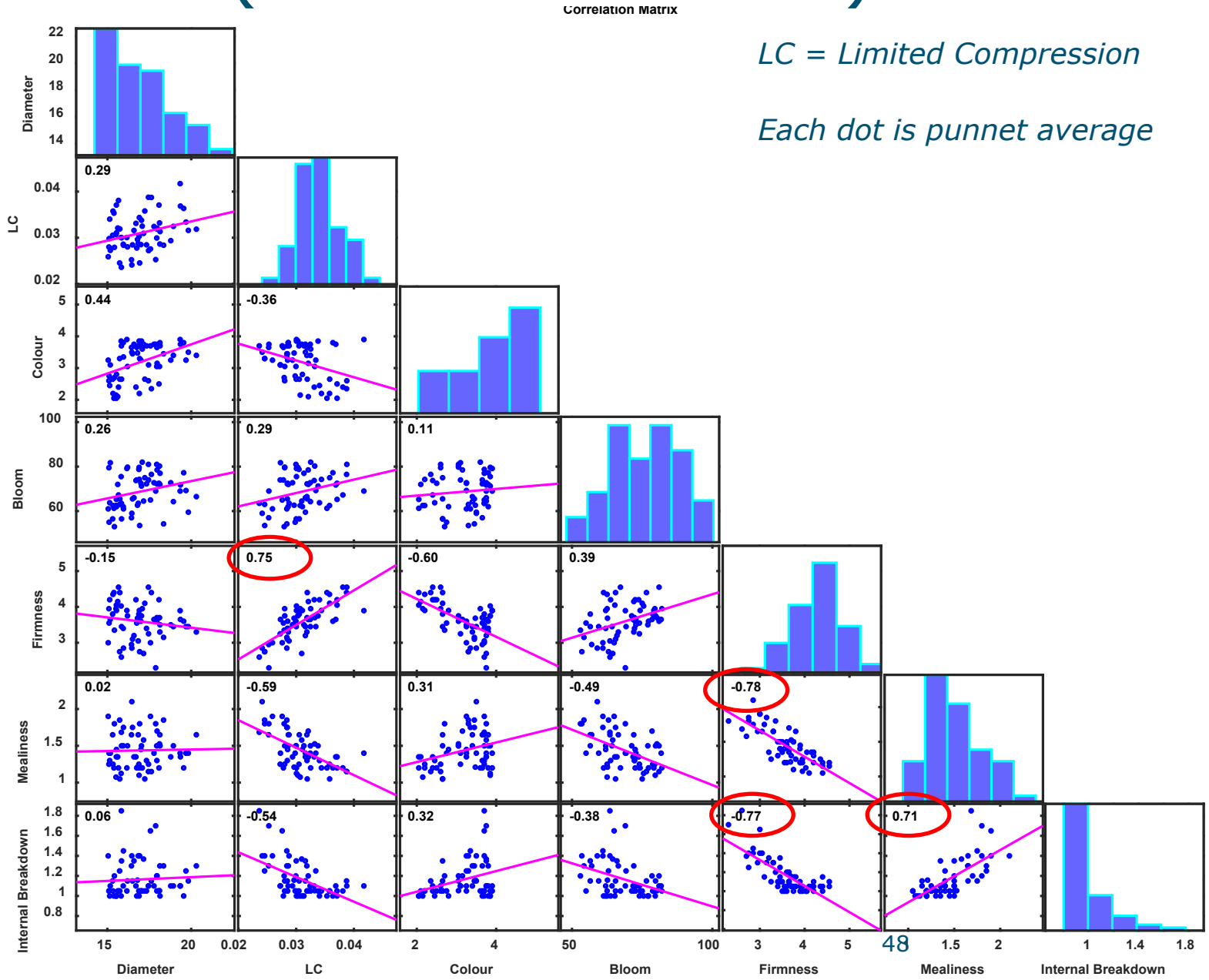


- SSC increased with ripeness, but decreased slightly with season progression
- TA decreased with ripeness and season progression
- Sugar/Acid ratio increased in ripeness and with season progression in ripe berries

3rd project year – Results (intercorrelations)

- Unlike 2020, the sensorial data from 2021 showed in general a good correlation
- No correlation bloom – Firmness (r=0.39)
- Some correlation colour – Firmness (r=0.60)
- Correlations (r) Fmax:

Correlation Fmax with:	
Firmness score	0.71
Mealiness score	0.57
Internal Breakdown score	0.45



LC = Limited Compression

Each dot is punnet average

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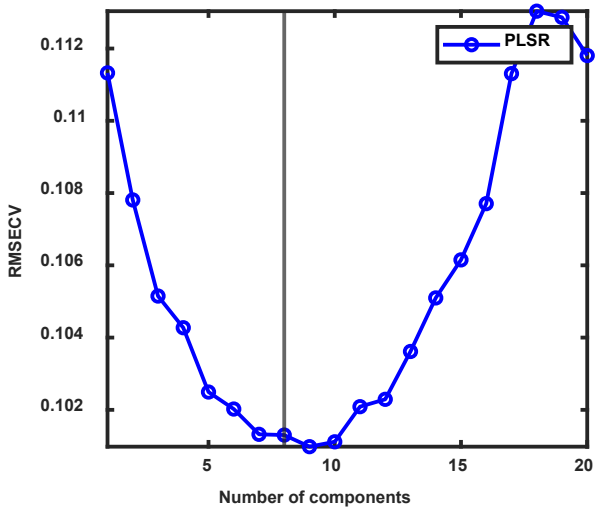
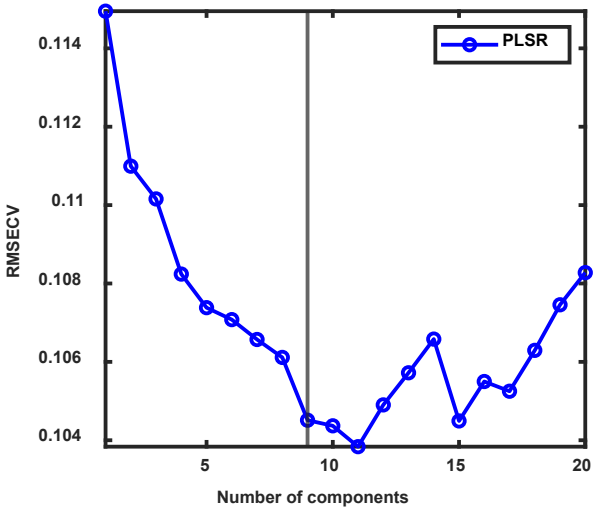
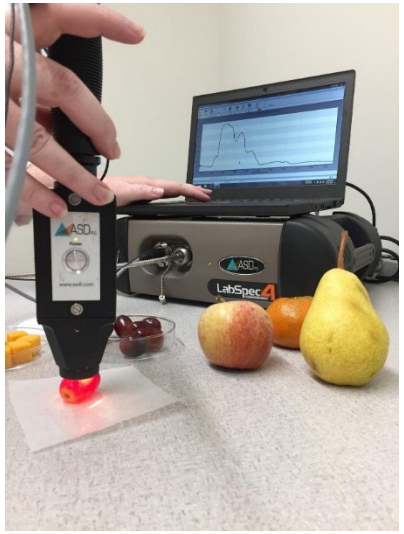
A comparison hyperspectral camera and point spectrometer **berry level** :

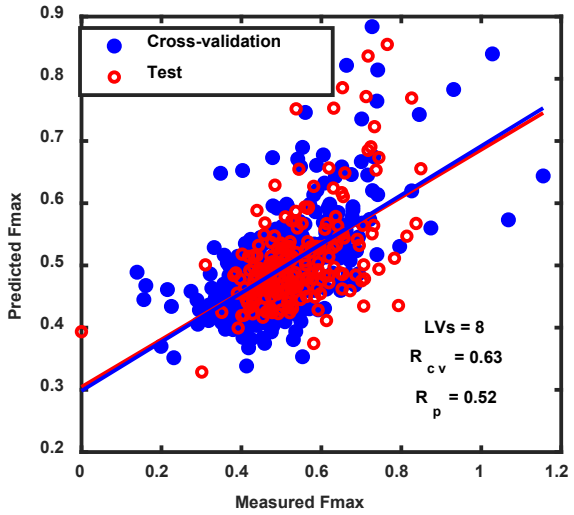
HSI (Hyperspectral Imaging)

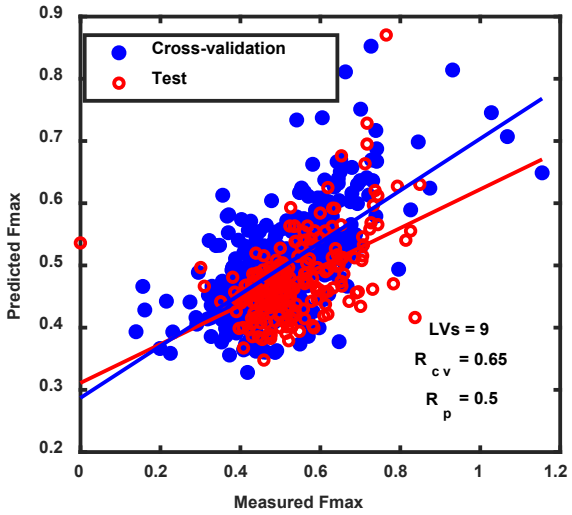






LabSpec (point spectrometer)





Independent test on mid season harvest

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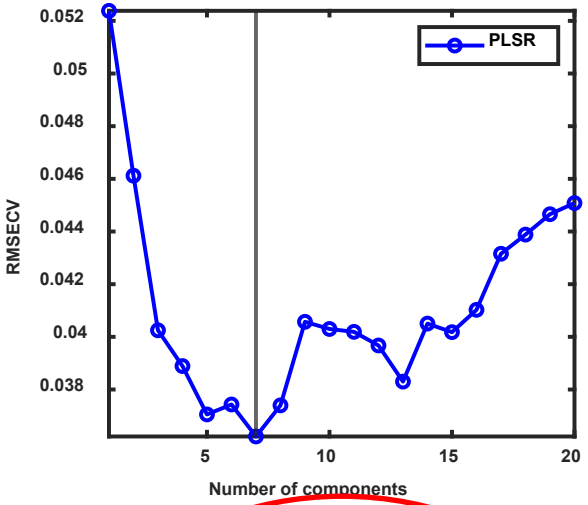
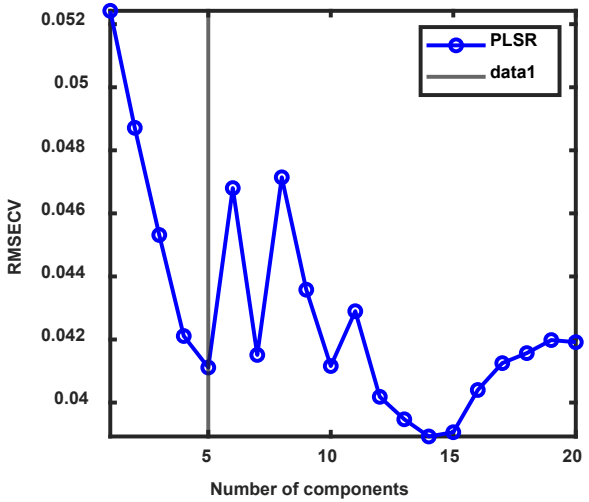
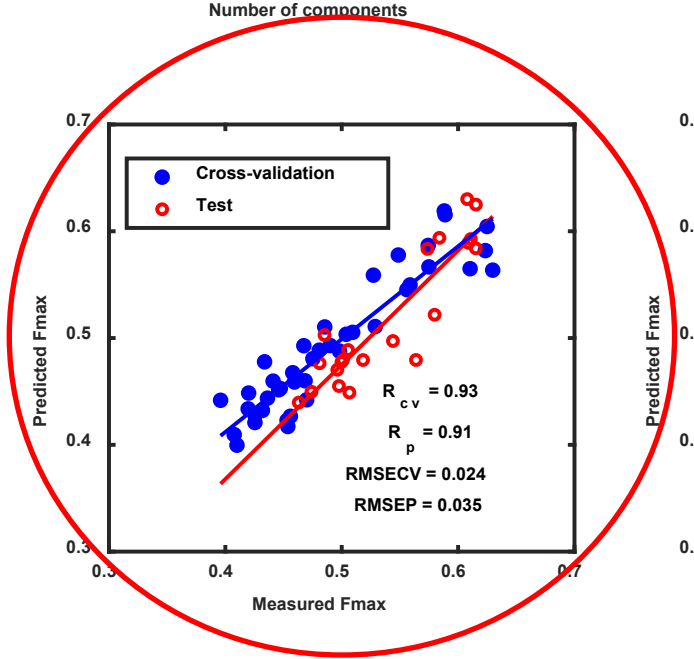
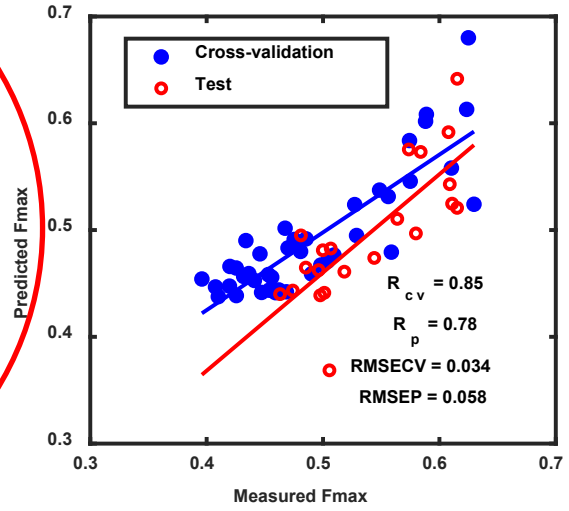
A comparison hyperspectral camera and point spectrometer

punnet level:









- Independent test on mid season harvest
- Accuracy increases a lot!

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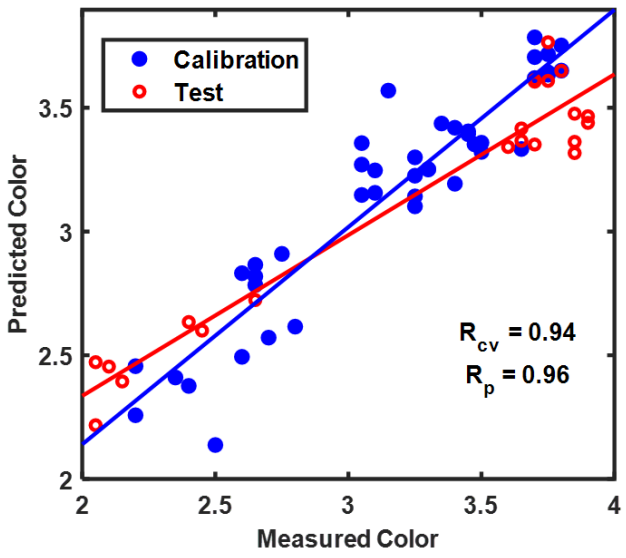
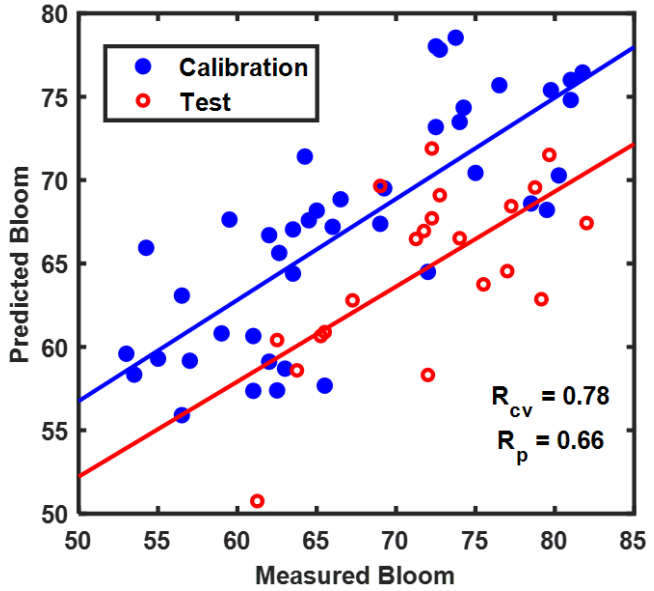
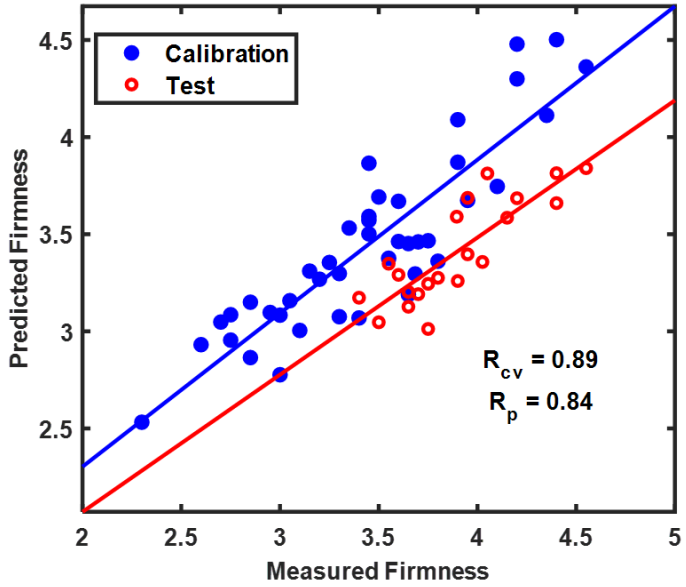
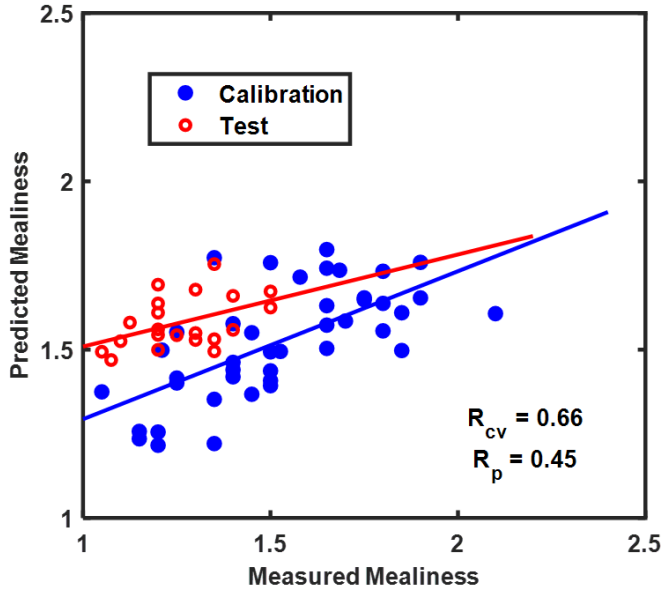
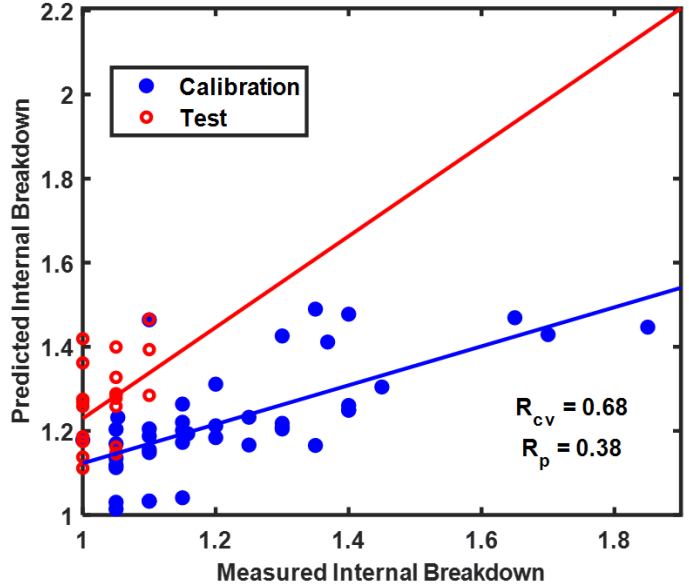
Assess sensorial parameters with HSI model











Models were trained on early and late harvest and tested on mid season harvest

OnePlanet Research Center

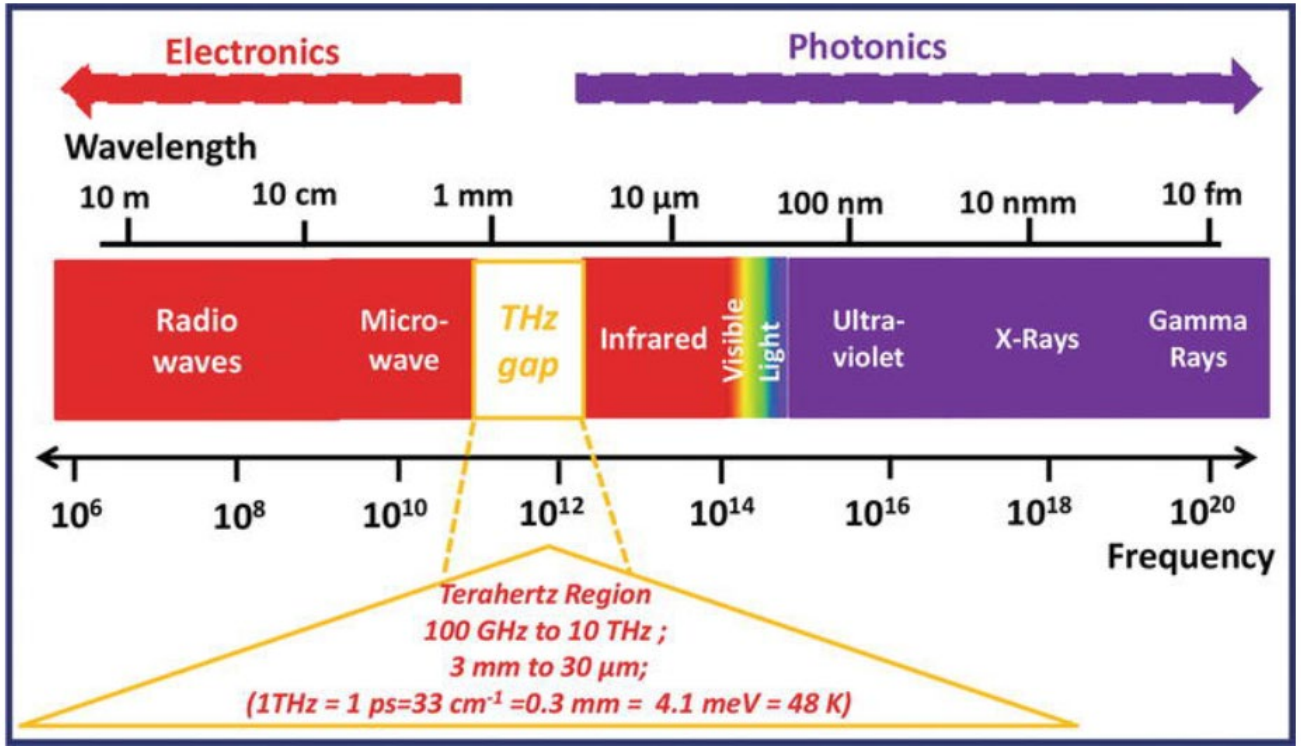
empowered by
imec, Wageningen University & Research, Radboud University and Radboudumc

Blueberry Ripeness Identification using THz Waves

Lei Zhang and Peter Offermans

Blueberry Ripeness Detection using THz Waves

- **Purpose**: Measure THz reflection spectrum off blueberry and correlate result to brix, NIR images, and limited compression
- **Equipment**: CW THz laser

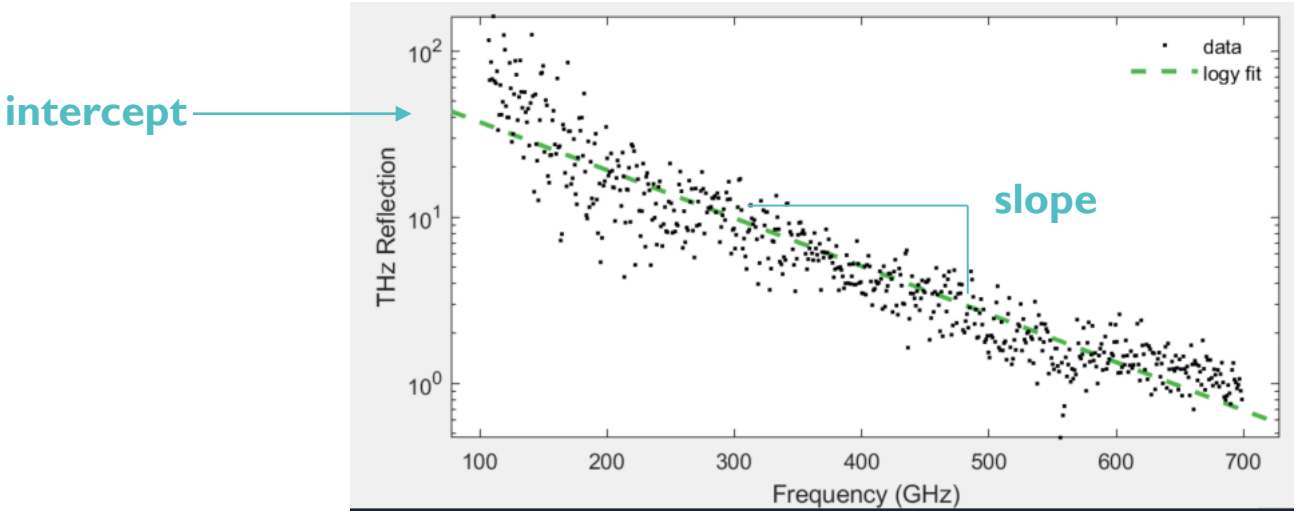


Setup for THz reflection measurement

Blueberry Ripeness Detection using THz Waves

- **Method**: Scan from 100 to 700 GHz in reflection mode. Correlate slope and intercept (offset) of the THz spectrum to the reference data.
  - Test-0: July 5 (brix of individual berries)
  - Test-1: August 5 (NIR, limited compression)
  - Test-2: August 19, Test-3: September 2 (limited compression)

Typical THz reflection spectrum and linear-log fit



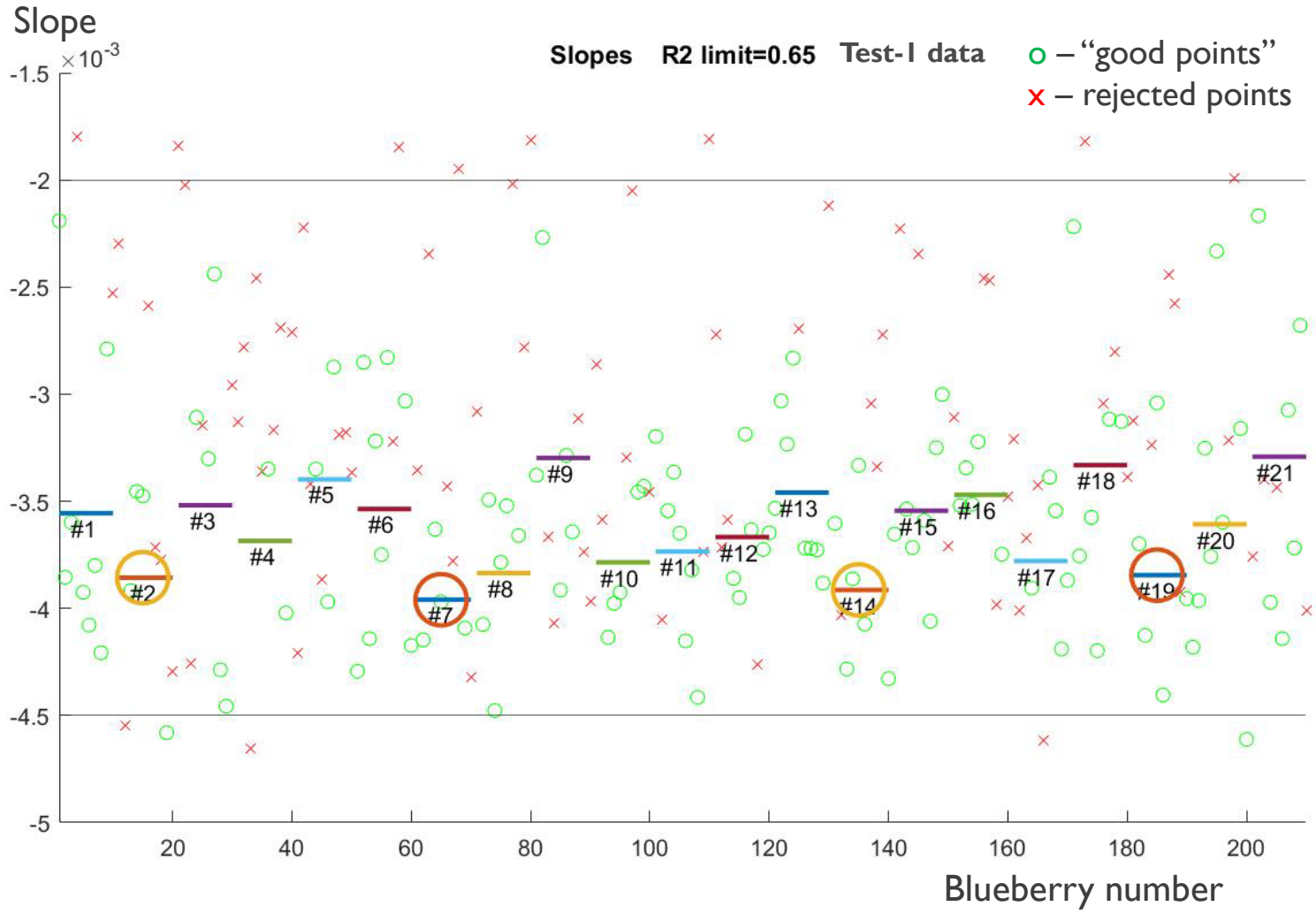
Setup for THz reflection measurement

Is THz Slope an indicator of ripeness?

Test-0 showed large variation in slope for *individual* blueberries, with only weak (R^2<0.4) correlation with brix (using refractometer)

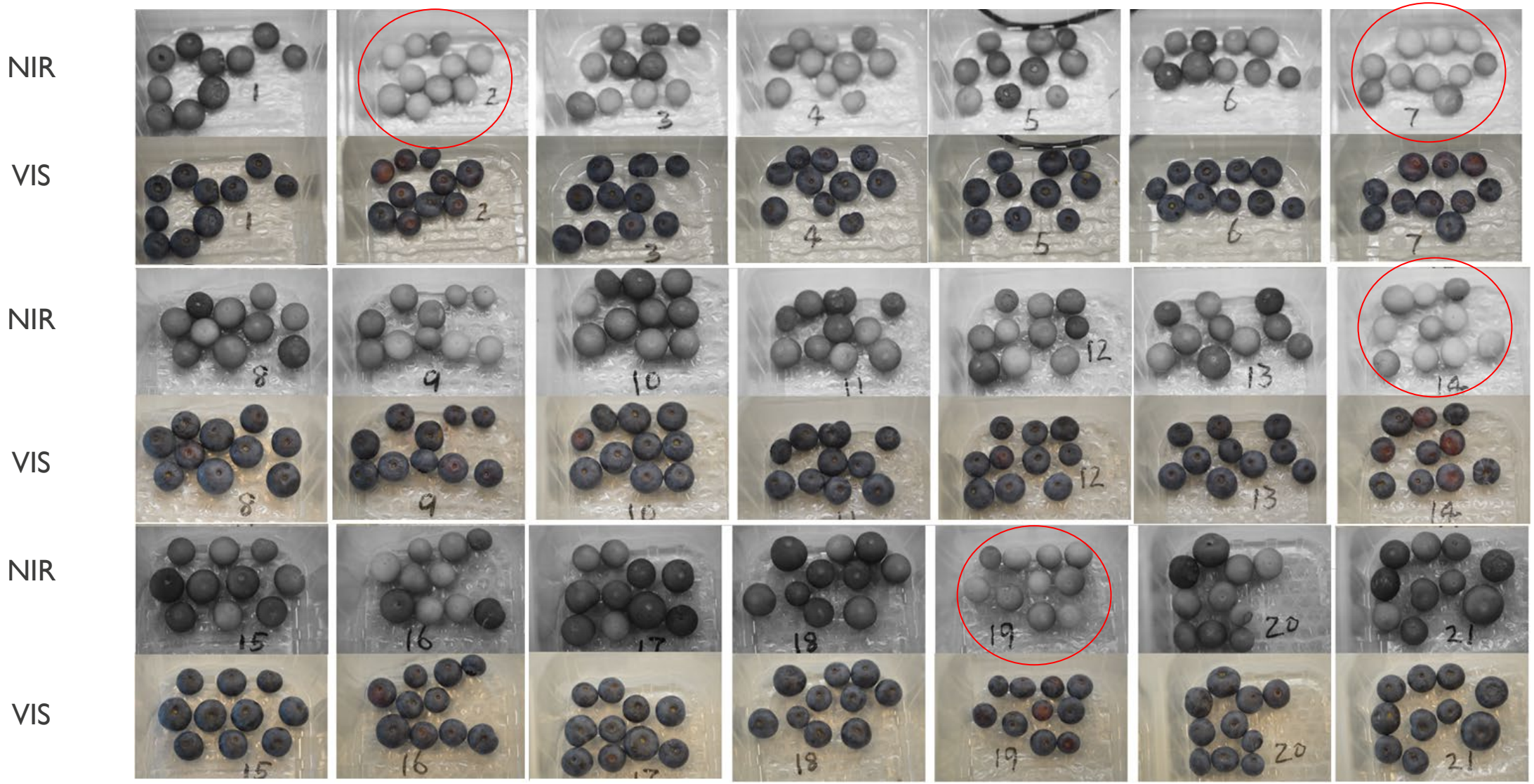
For Test-1, 210 blueberries were divided into 21 groups (boxes) and each box was also imaged with a NIR camera

- THz spectra that could not be fitted linearly were rejected (x)
- The measured slope values in each group were averaged (horizontal bars)
- The 4 groups with lowest slope are indicated with a circle and compared to NIR images



The 4 groups with lowest averaged slope correspond to low ripeness! This is confirmed with NIR images

NIR blueberry images obtained using a full spectrum camera with an 850nm high pass filter may also be used for ripeness identification

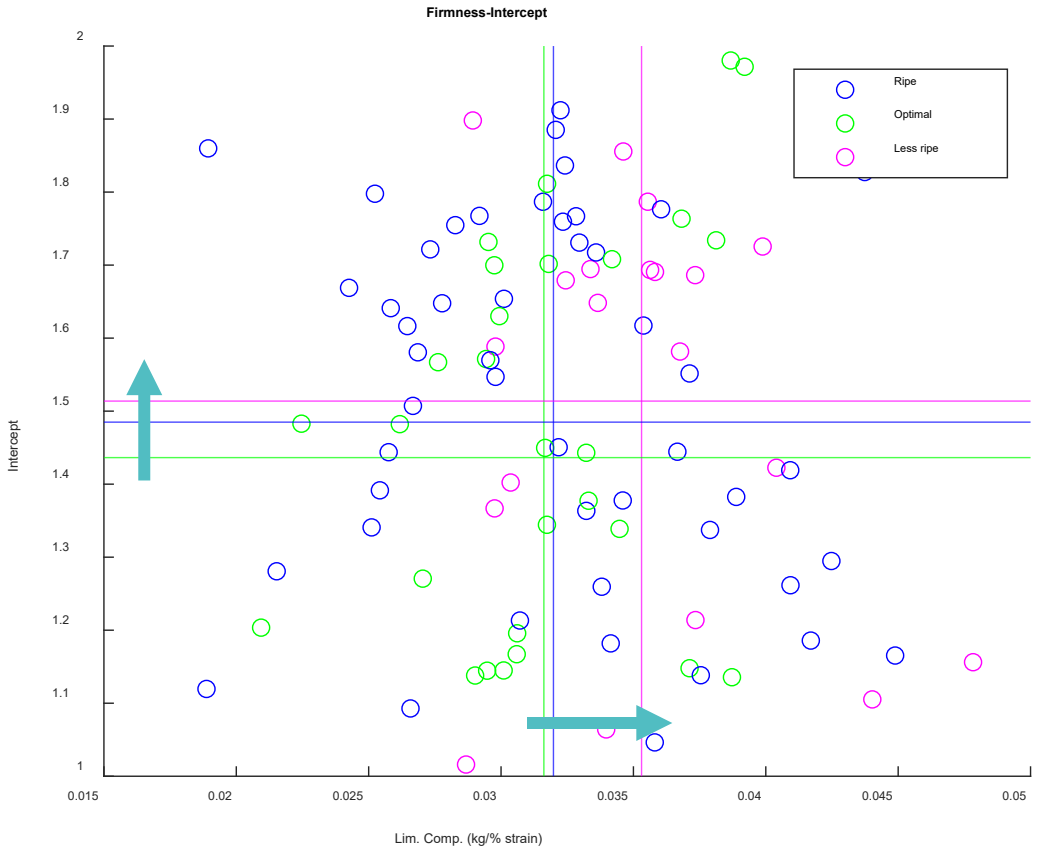


Low THz slope corresponds to low ripeness as determined from NIR images

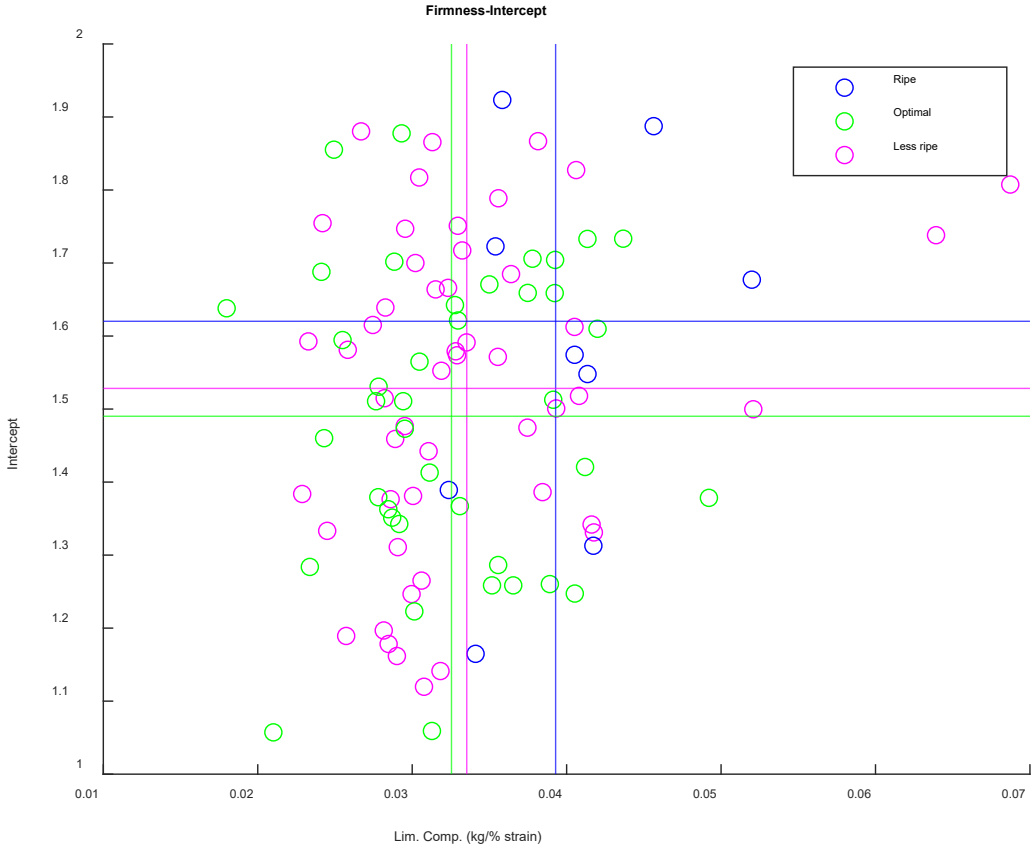
Is THz intercept an indicator of firmness?

- For Test-2 and Test-3 the THz intercept is plotted against the limited compression results for all ripeness levels

Test-2 Group 14 (100 blueberries)



Test-2 Group 15 (100 blueberries)

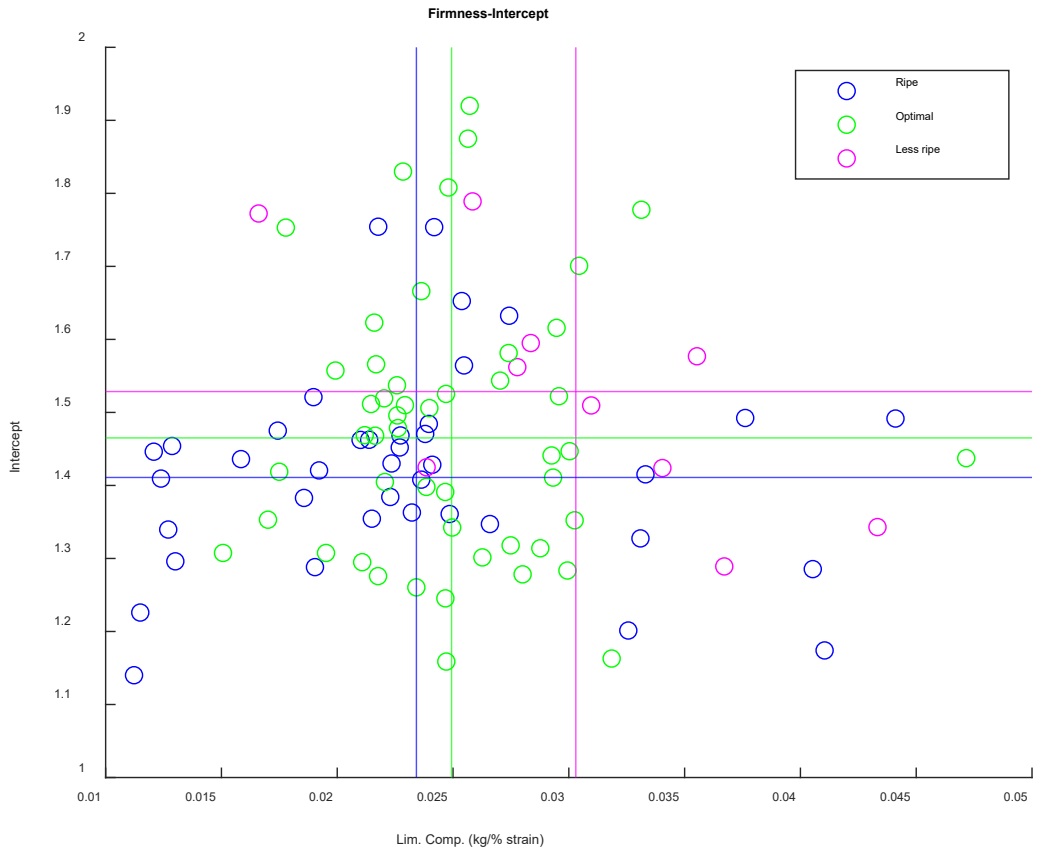


THz intercept follows the same trend as the limited compression!

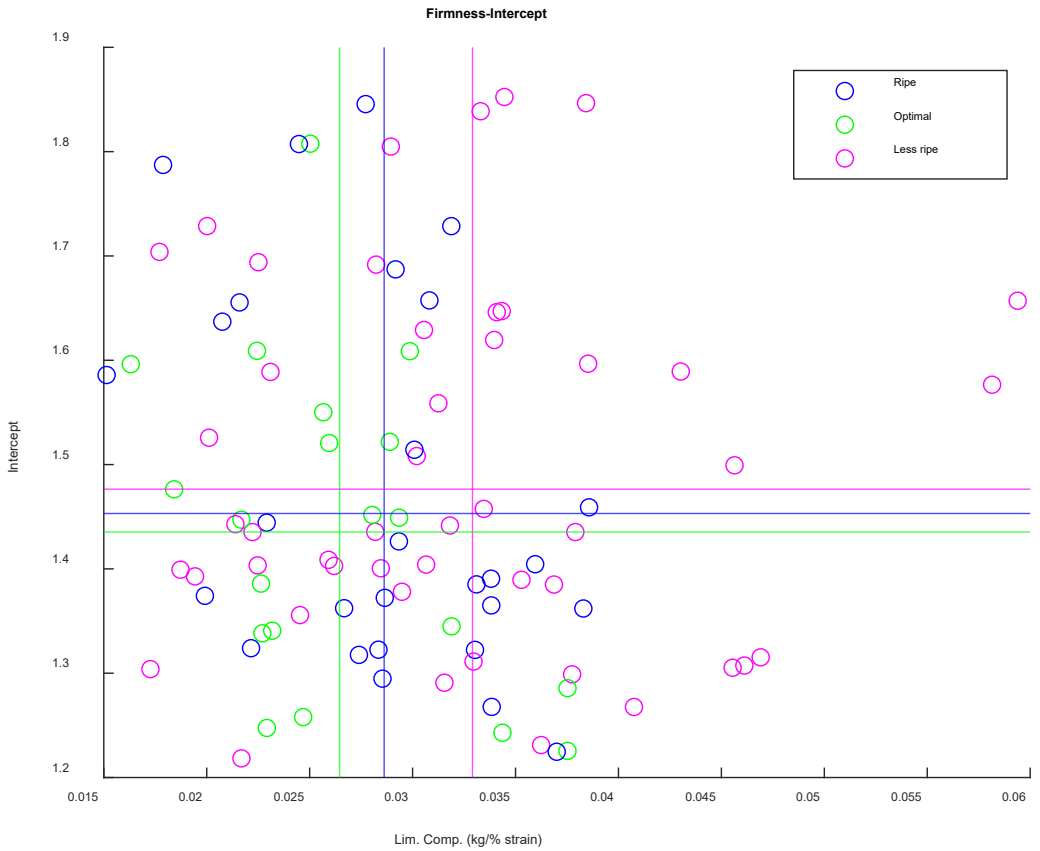
Is THz intercept an indicator of firmness?

- Repeated study in Test-3 shows same trend between THz intercept and limited compression.

Test-3 Group 14 (100 blueberries)



Test-3 Group 15 (100 blueberries)



THz intercept follows the same trend as the limited compression!
High firmness → high THz reflection

3rd project year – Conclusions I

- Very good correlation NIR hyperspectral imaging measurements and Fmax at punnet level (test set-> R=0.91; RMSEP=0.35)
- The new hyperspectral imaging system (HSI cabinet) allowed better prediction of Fmax at punnet level then the point spectrometer (ASD Labspec)*
- Also good correlations between NIR and sensorial parameters colour (R=0.96) and firmness (R=0.84) and LC (R=0.77) were found
- Reasonable correlation with bloom (R=0.66)
- Good agreement between Fmax and Turoni-> confirms performance of the measuring method

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** For this reason the data of 2021 and 2022 is not merged into 1 model*

3rd project year – Conclusions II

- Fmax remains constant over de season
- Mealiness and Internal Breakdown (IB) higher in late season berries (as expected?)
- Mealiness increases with ripeness level
- IB: effect ripeness only clear in late season
- Diameter of berries decreases over de season

3rd project year – Conclusions III

- Sensorial assessment is improved! (Firmness score and Fmax similar results)

- Emerging sensors:
  - THz: Correlation with limited compression at the moment not strong enough but there are similar trends!
  - Ultra-sound: probe development was very much delayed
  - Microwave probing: not tested; One Planet expects that the berries will be too small for this sensor/probe

Content

- Kick-off project
- First year– Focus mealiness (2019)
- Second year- Focus non-destructive texture method (2020)
- Third year– Improve texture method; Develop HSI assessment method (2021)
- **Fourth year – Validation & company implementation (2022)**
- Final project conclusions

4th project year – Validation & Implementation

Project activities (slide 73-88):

- Validate the model to the limit:
  a) different cultivars
  b) different growers/different production locations
  c) different distribution chains (export/production in NL)
- Adjust the method + model for in-company implementation
  a) image acquisition direct on punnet/box or roll berries out on a plate
  b) translation Fmax to international standard/sensorial evaluation score

4th project year – Other topics

Project activities:

- Establish accuracy and sample size (statistical analysis)-> slide 65
- Quantification of batch heterogeneity (in addition to average firmness) -> slide 89
- Make the link to Baxlo (because Baxlo is the global accepted standard) -> slide 90/91
- Since the data is available present the relationship between HSI model and 1) limited compression measurements -> slide 92/93

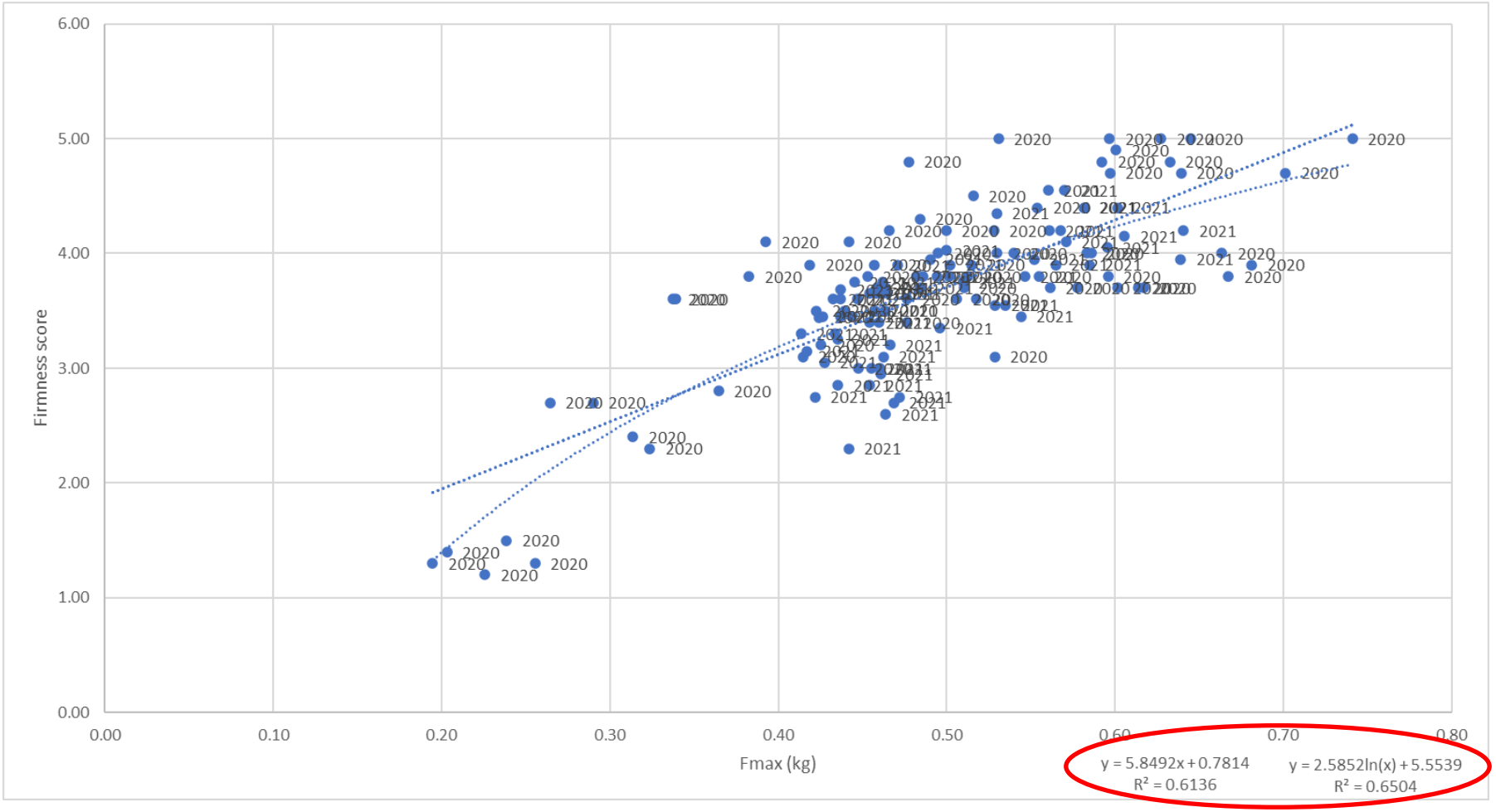
  2) sensorial evaluation -> slide 94-97

4th project year – Establish accuracy and sample size

How to define accuracy?

- The sensorial evaluation of firmness gives a starting point!
- During the training for the sensorial evaluation we concluded that a 0.5 score point difference between judges was acceptable-> use this value as the basic firmness accuracy
- But how to translate this value to Fmax?

Define accuracy: Relation Fmax and Firmness score



Data 2020 and 2021 together

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Define accuracy

How much is 0.5 firmness score in Fmax?

- Used both mathematical equations:

Firm score	Fmax	Verschil 0.5 is:
5	0.80714	0.141939507
4.5	0.665201	0.116978753
4	0.548222	0.09640747
3.5	0.451814	0.079453747
3	0.372361	0.065481419
2.5	0.306879	0.053966193
2	0.252913	0.044475975
1.5	0.208437	0.036654658
1	0.171782	0.030208758
0.5	0.141574	0.024896401
0	0.116677	
Average:		**0.069046288**

Firm score	Fmax	Verschil 0.5 is:
5	0.721227	0.085481775
4.5	0.635745	0.085481775
4	0.550263	0.085481775
3.5	0.464782	0.085481775
3	0.3793	0.085481775
2.5	0.293818	0.085481775
2	0.208336	0.085481775
1.5	0.122854	0.085481775
1	0.037373	0.085481775
0.5	-0.04811	0.085481775
0	-0.13359	
Average:		**0.085481775**

- Conclusion: set accuracy Fmax at ± 0.07 (kg);
- Lower value selected ->higher descriminate power between batches/higher method robostness.

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Define accuracy

- Additional looked also at Limited Compression and Turoni

- Set the accuracy at:
    - Turoni: ± 1.0
    - Limited compression: ± 0.007

4th project year – Establish accuracy and sample size

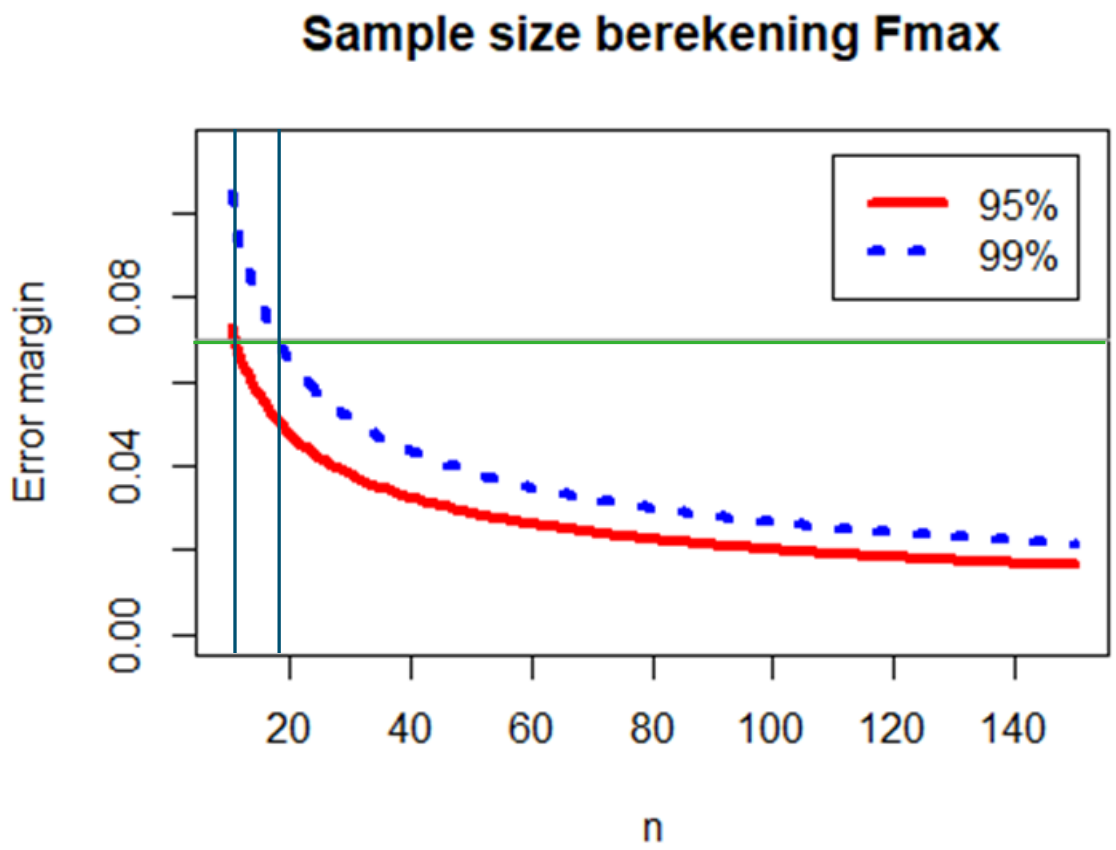
Define how many berries to be measured/ sample size

- Statistical method: $\bar{y} \pm \text{error margin}$

$$\bar{y} \pm t_{\alpha/2} * s/\sqrt{n}$$

  - *y = average measurement*
  - *t(a/2) = t-distribution value at n-1 degrees of freedom*
  - *s = standard deviation* -> calculate based on the data of previous years
  - *n = number of berries*

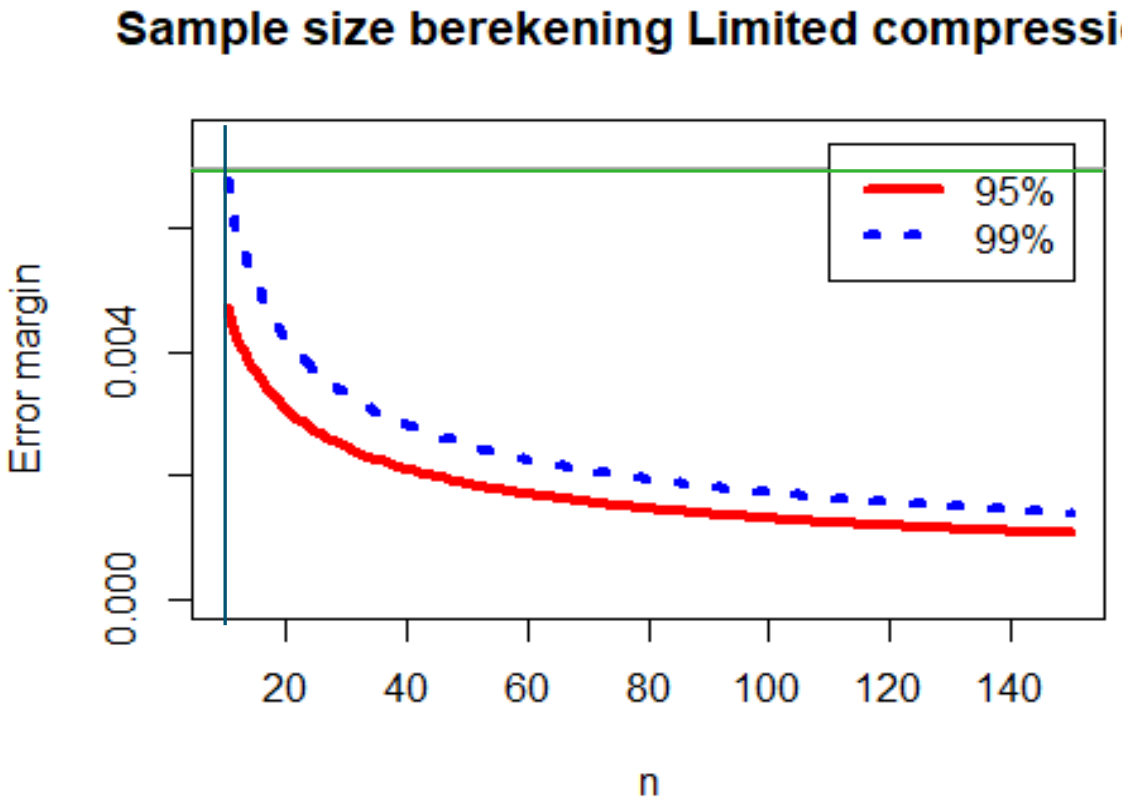
Sample size Fmax



Accuracy Fmax at ± 0.07 (kg)

Less than 20 berries

Sample size Limited Compression (LC)



Accuracy Limited compression: ± 0.007

Less than 10 berries

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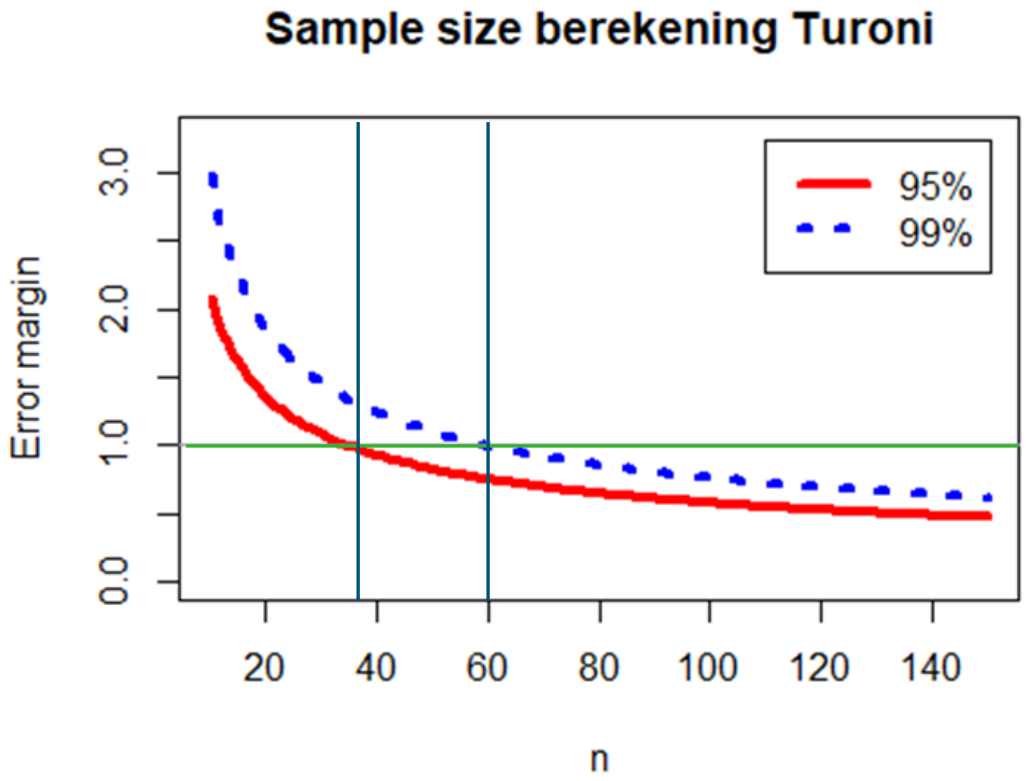
Sample size Turoni



Accuracy Turoni ±1

Minimal 40 or 60 berries

4th project year – Validation Test set up March 2022

Export batches

- Mixto
  - Juan I.
  - Mixto
- Elliot
  - Grower A (or C)
  - ~~Grower B (or D)~~
- Legacy
- Brigitta

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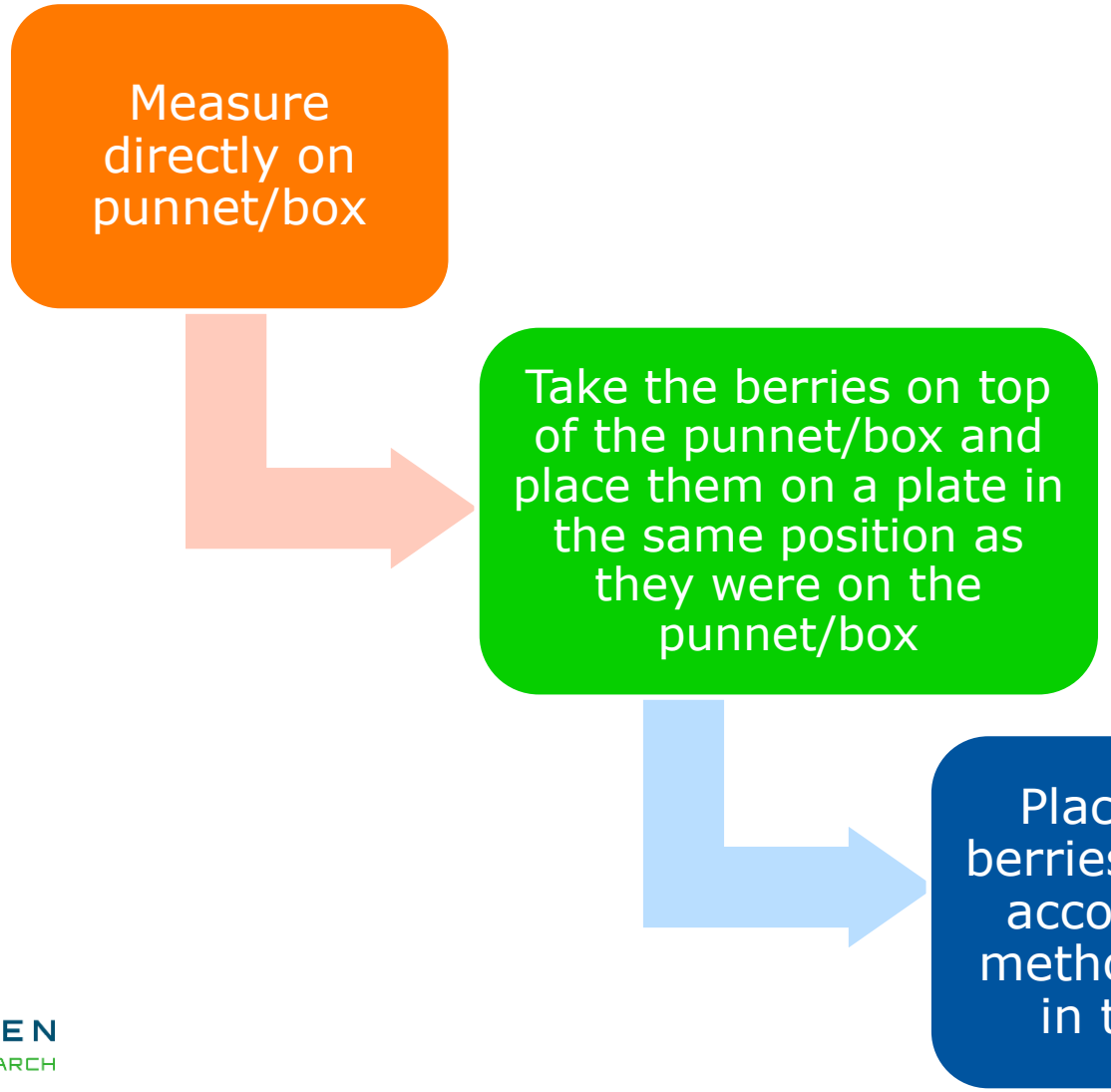
4th project year - Test set up in-company implementation March 2022



= simulation of rolling out the berries

4th project year – Validation test set up Summer 2022

Local production batches

- Duke
  - Criens
  - Van IJken
- Liberty
  - Magoley
  - Van IJken
- Top Shelf
  - Blueberry garden
- Valor
  - Blueberry garden
- Draper
  - Koops

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4th year– Test in-company implementation Summer 2022

Roll the berries on te cabinet

= simulation of rolling out the berries

Take 5 berries per quadrant and place on the plate in the same position as they were on the cabinet

Place the same berries on the plate according to the method developed in the project

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4th project year – test set up

- Data set 1:

Hyperspectral camera* -> Baxlo -> Turoni -> Limited Compression -> Fmax

- Data set 2:

Hyperspectral camera ->Limited Compression ->Baxlo ->Turoni -> Sensorial assessment

* The hyperspectral measurements were done sequencely on 3 different ways according to the scheme in the previous slide

Results: intercorrelations (data March 2022)

Data March 2022

Correlation (r) Fmax with:

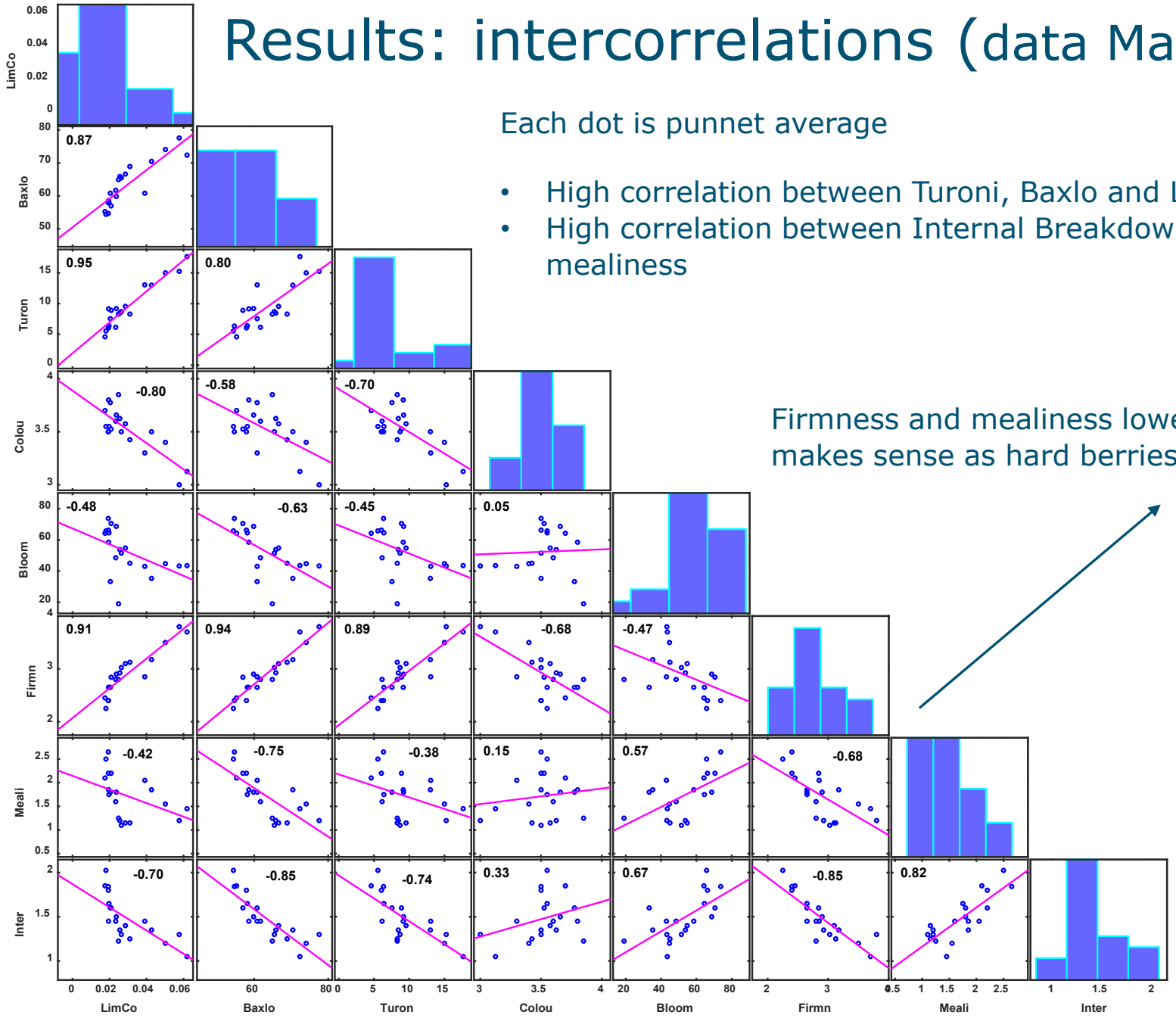
Baxlo =0.50

Turoni=0.70

Each dot is punnet average

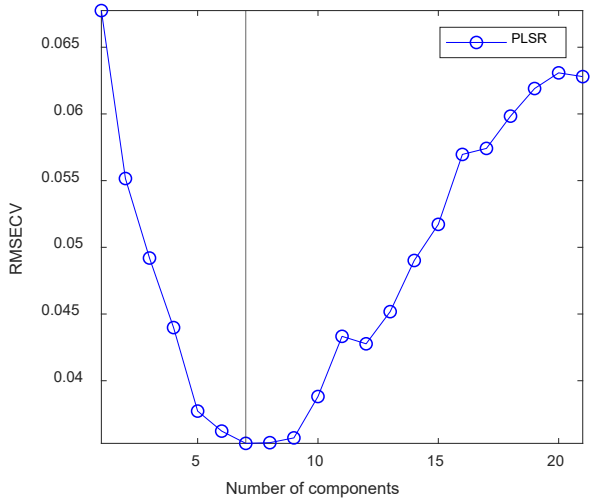
- High correlation between Turoni, Baxlo and Limited compression
- High correlation between Internal Breakdown, firmness and mealiness

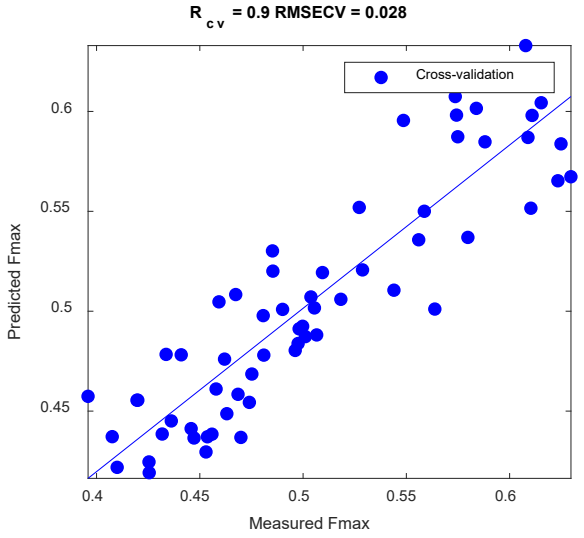
Firmness and mealiness lower than Firmness IB; makes sense as hard berries can be mealy...

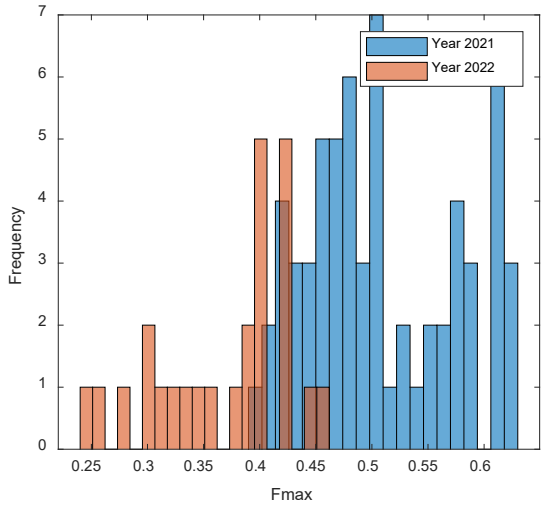


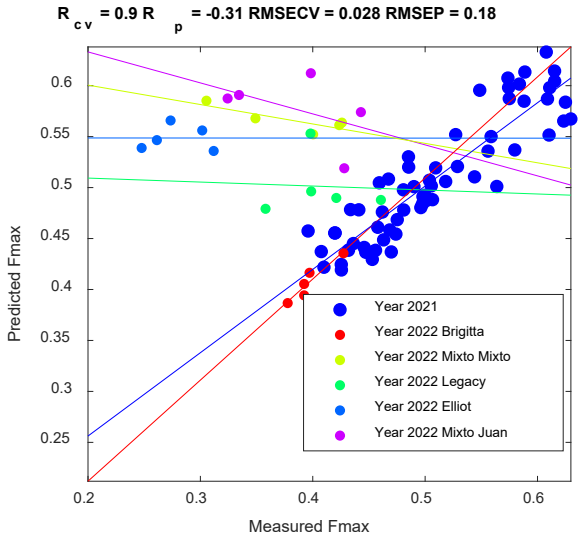
Results March: Validation HSI-Fmax model from year 2021 on data from March 2022 (on side)

Camera





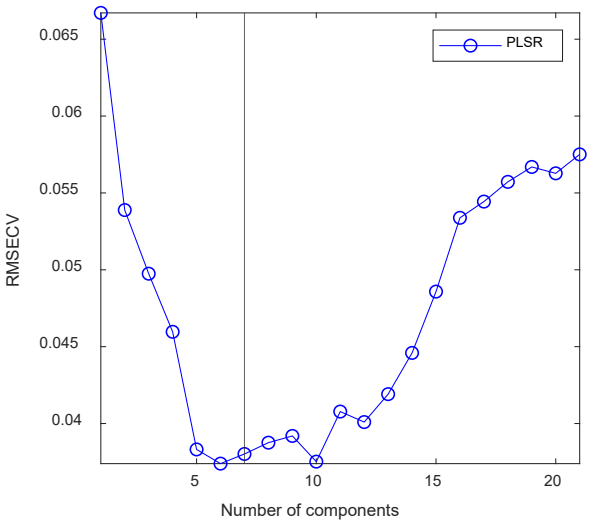


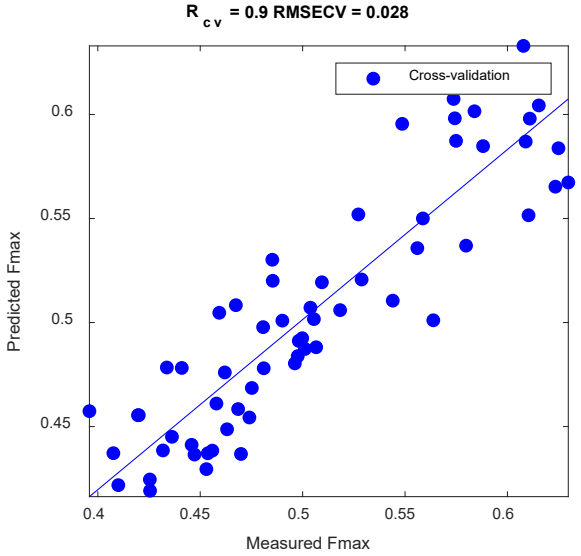


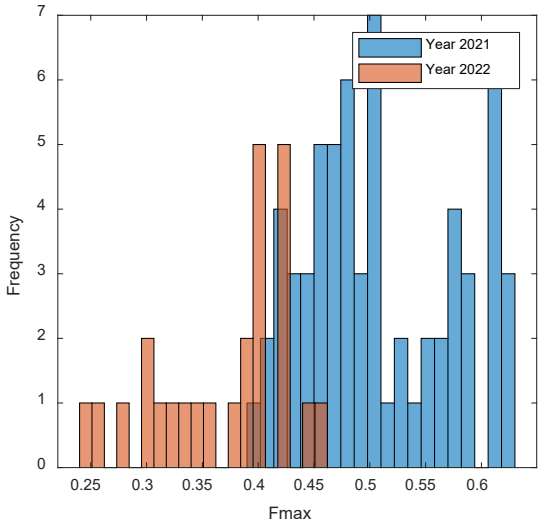
The model worked well only for Brigitta while failed for other cultivars

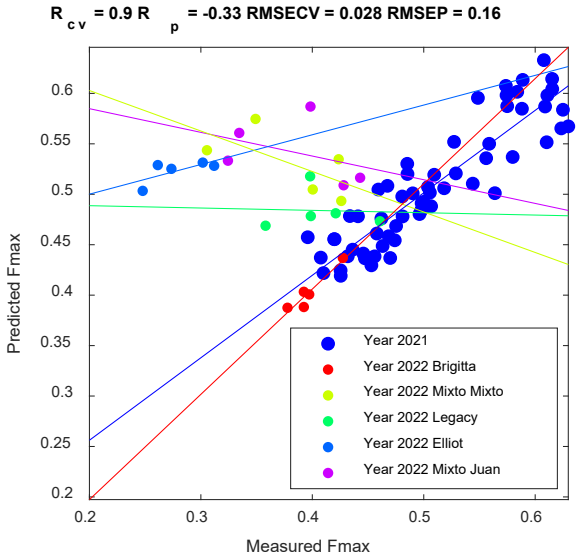
Results March: Validation HSI-Fmax model from year 2021 on data from Mach 2022 (random berry position)

Camera









The model worked well only for Brigitta while failed for other cultivars

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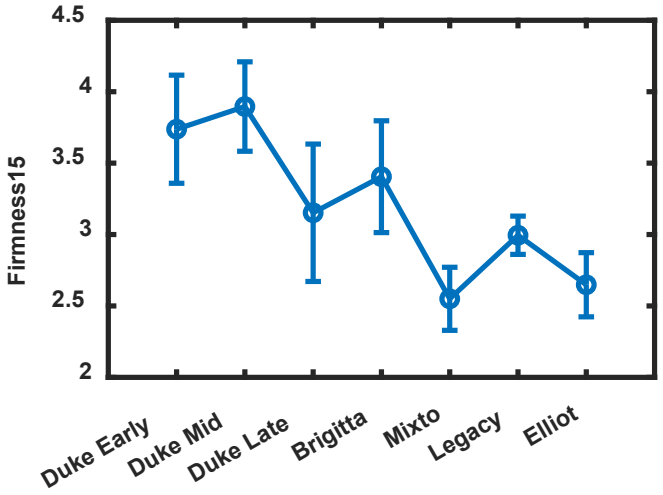
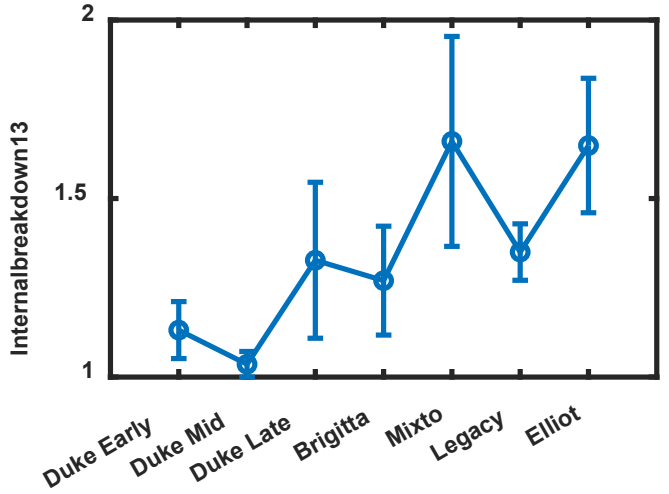
Why is only Brigitta well predicted?



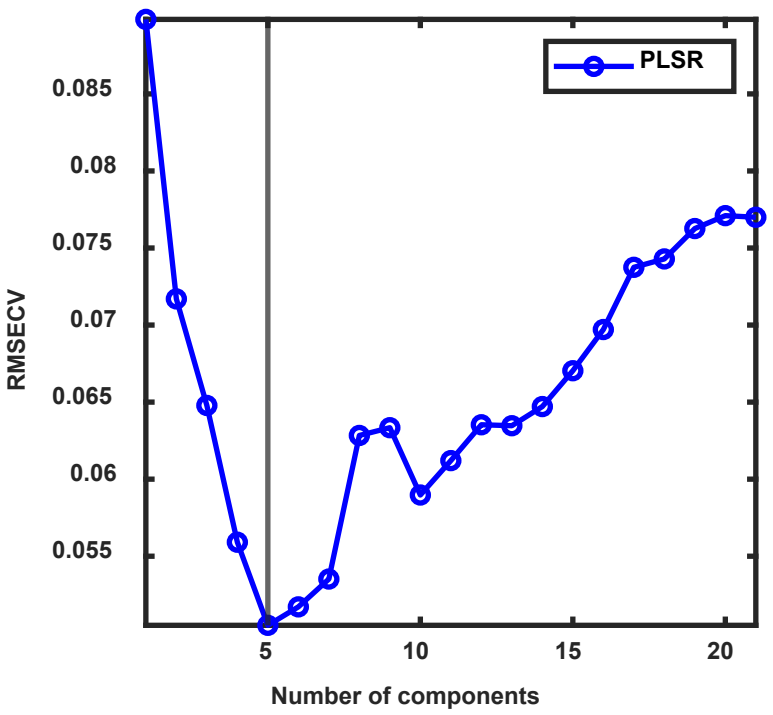


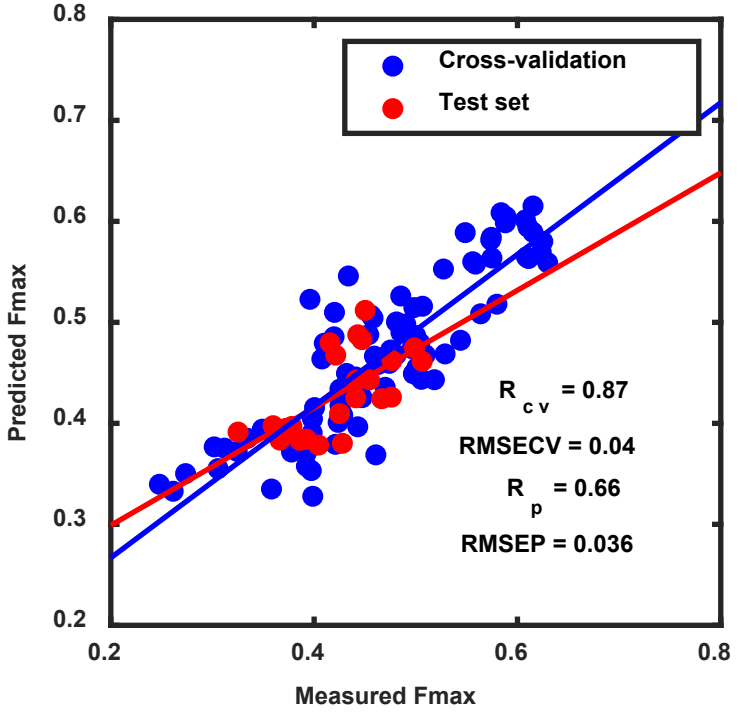
Average characteristics of different cultivars (including Duke from 2021)

- Brigitta has similar level of internal breakdown and firmness compared to Duke from 2021 (model was built on Duke)
- This could be the reason while model worked well on Brigitta samples

Results Summer 2022: Validation HSI-Fmax model 2021 extended with samples from March 2022 (on side)

- Fmax model 2021 was extended with samples from cultivars measured March 2022 (blue dots)
- Validating on independent samples (red dots) – berries measured on their side (see pic below)



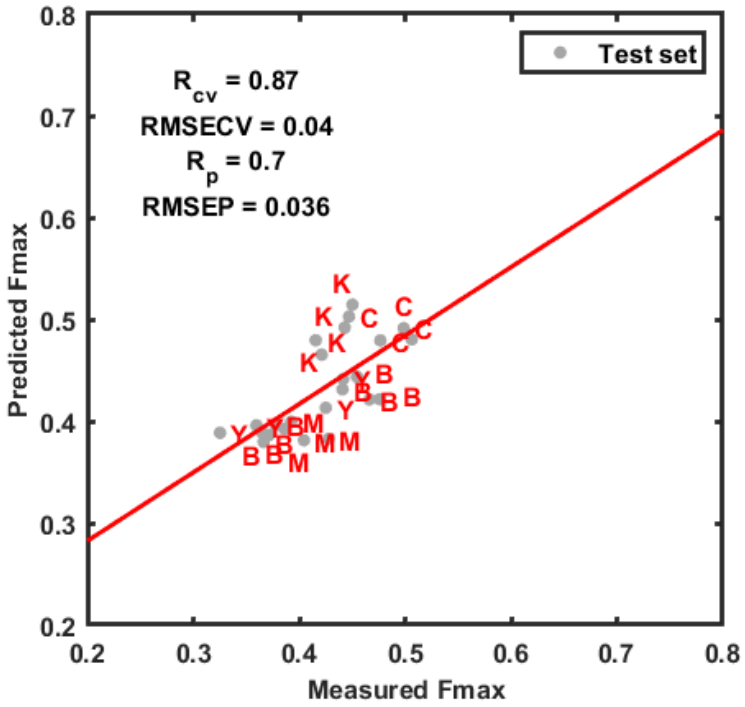


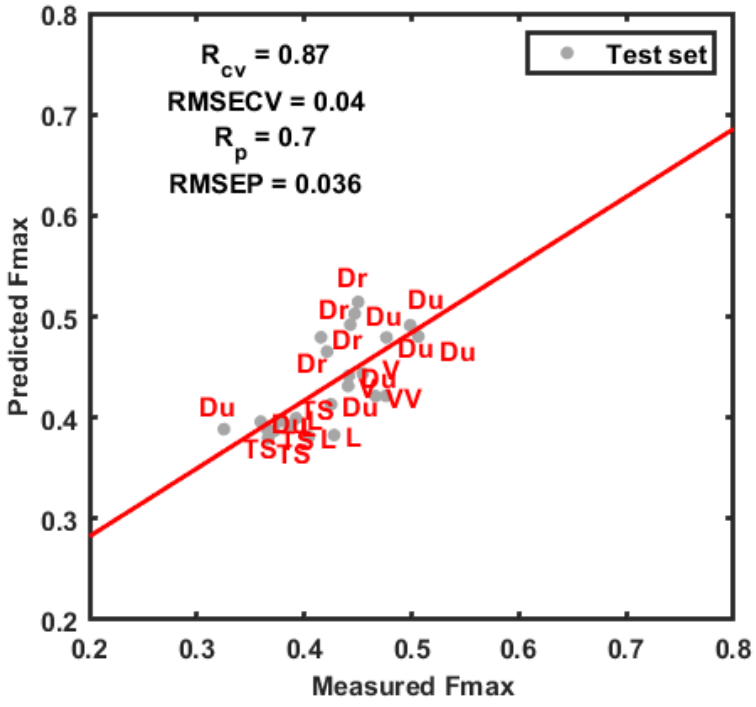
- The new independent sample set were predicted without any bias

Results Summer 2022: Validation HSI-Fmax model (on side)

Details of the test set results showing the performance per cultivar and grower

Grower
Y = Yken
K = Koops
C = Criens
M = Magoley
B = Blueberry Garden

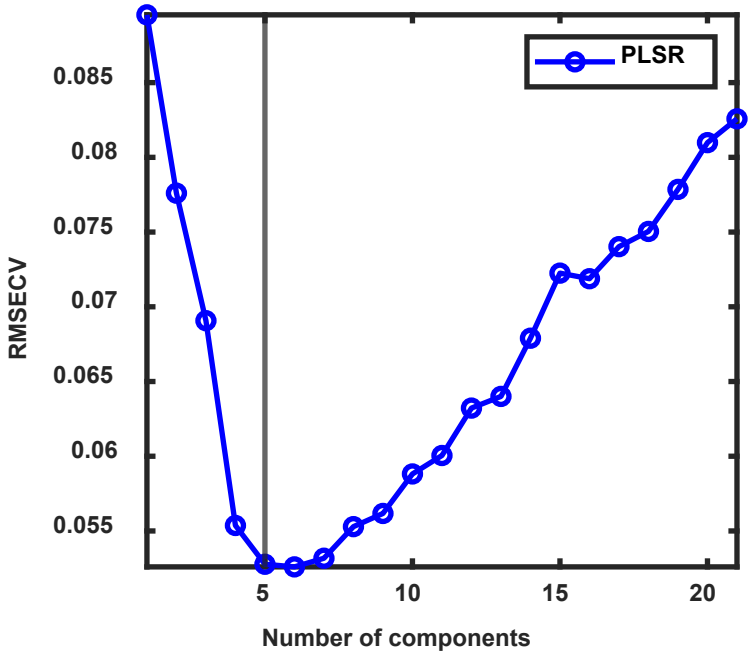


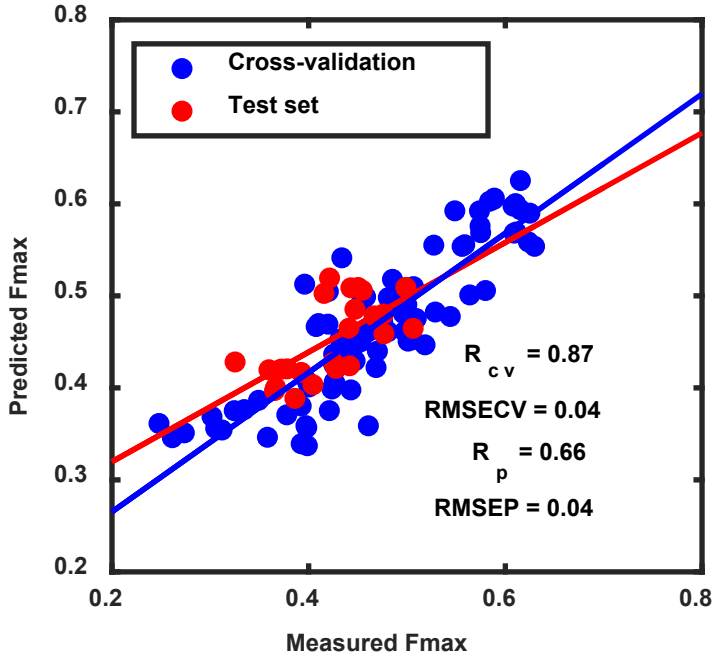


Cultivar
Du = Duke
Dr = Draper
L = Liberty
V = Valor
TS = Top Shelf

Results Summer 2022: Validation HSI-Fmax model 2021 extended with samples from march 2022 (random position)

- Fmax model 2021 was extended with samples from cultivars measured March 2022 (blue dots)
- Validating on independent samples (red dots) – random position





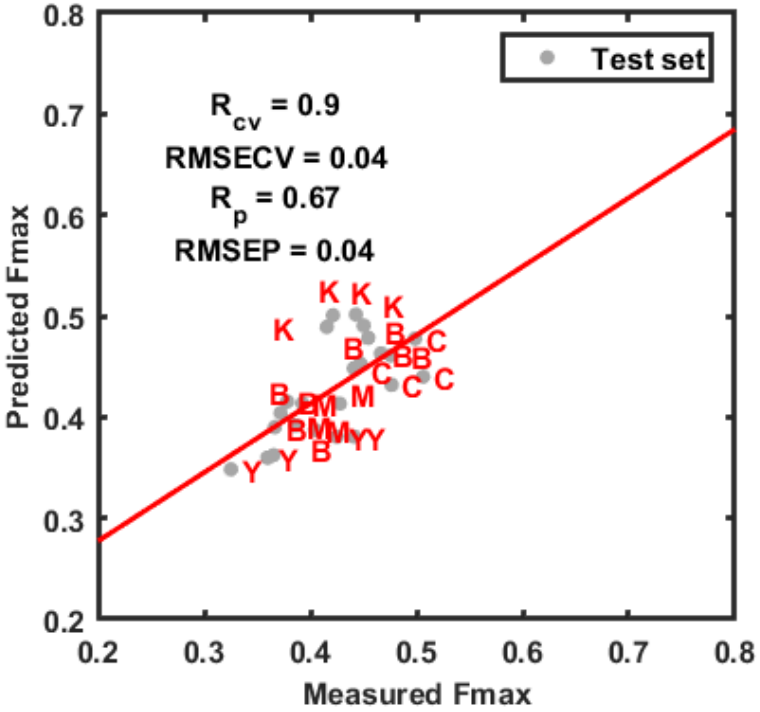
Camera

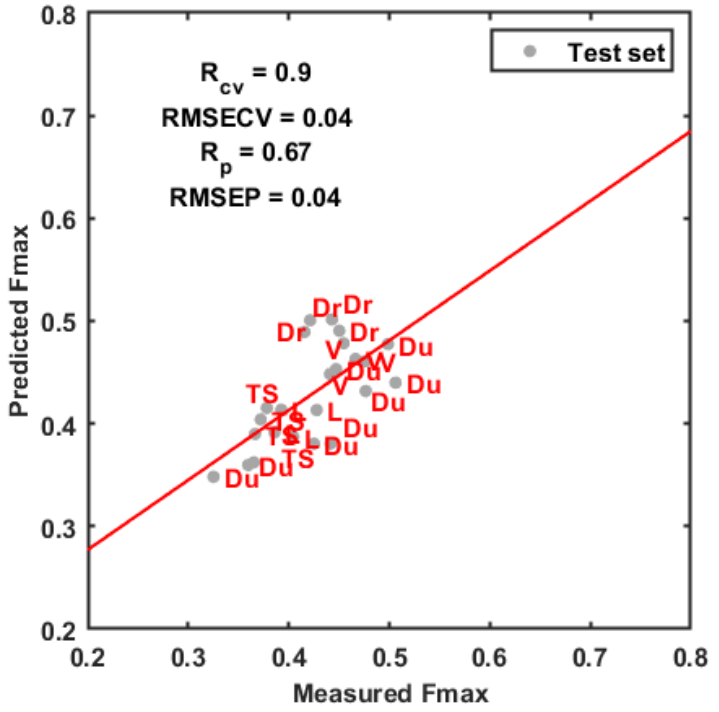
- The new independent sample set were predicted without any bias

Results Summer 2022: Validation HSI-Fmax model (random position)

Details of the test set results showing the performance per cultivar and grower

Grower
Y = Yken
K = Koops
C = Criens
M = Magoley
B = Blueberry Garden



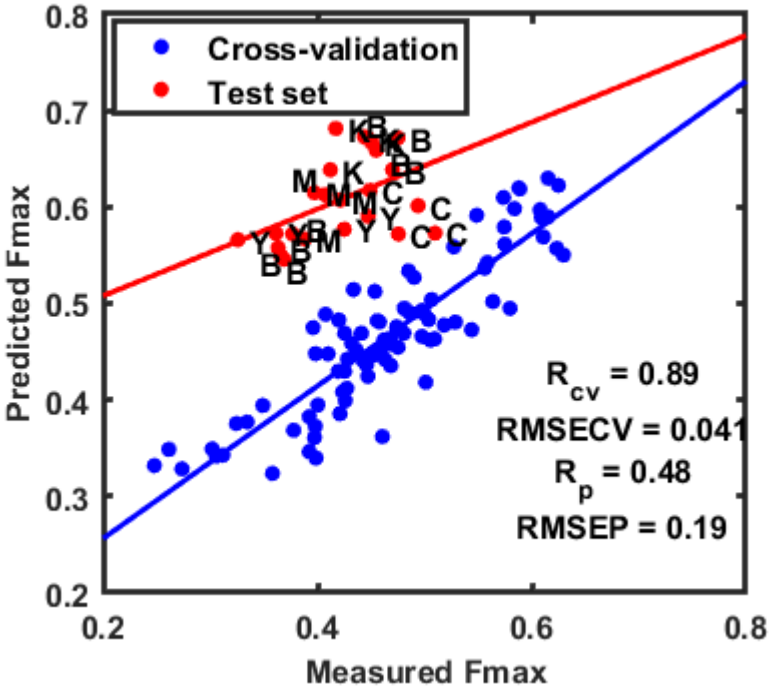


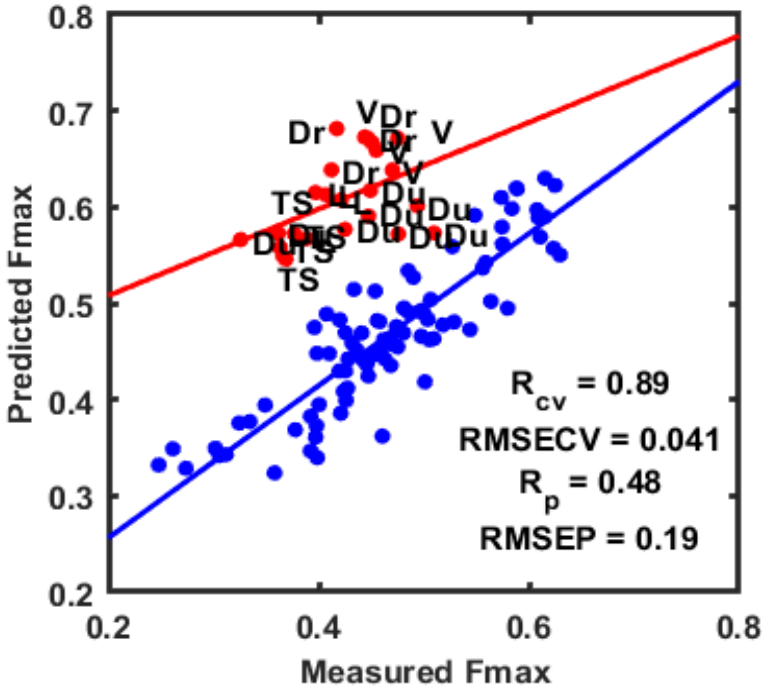
Cultivar
Du = Duke
Dr = Draper
L = Liberty
V = Valor
TS = Top Shelf

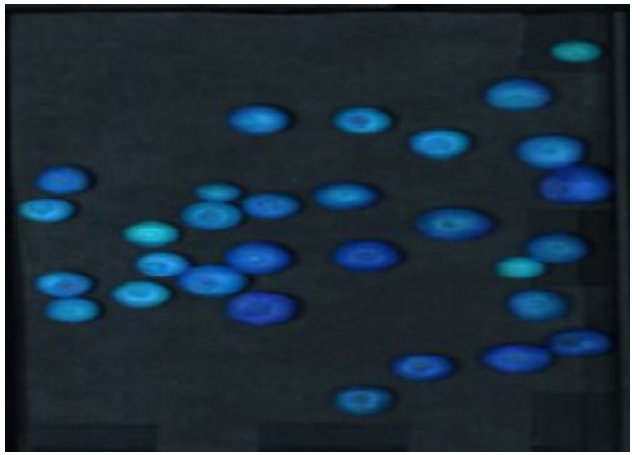
Test in-company implementation Summer 2022

Grower
Y = Yken
K = Koops
C = Criens
M = Magoley
B = Blueberry Garden

Cultivar
Du = Duke
Dr = Draper
L = Liberty
V = Valor
TS = Top Shelf







- Direct application of the model (made on blue trays) to measure berries rolled from the package on a black surface
- High bias was noted when the model made on blue plate was used directly on samples on a black surface

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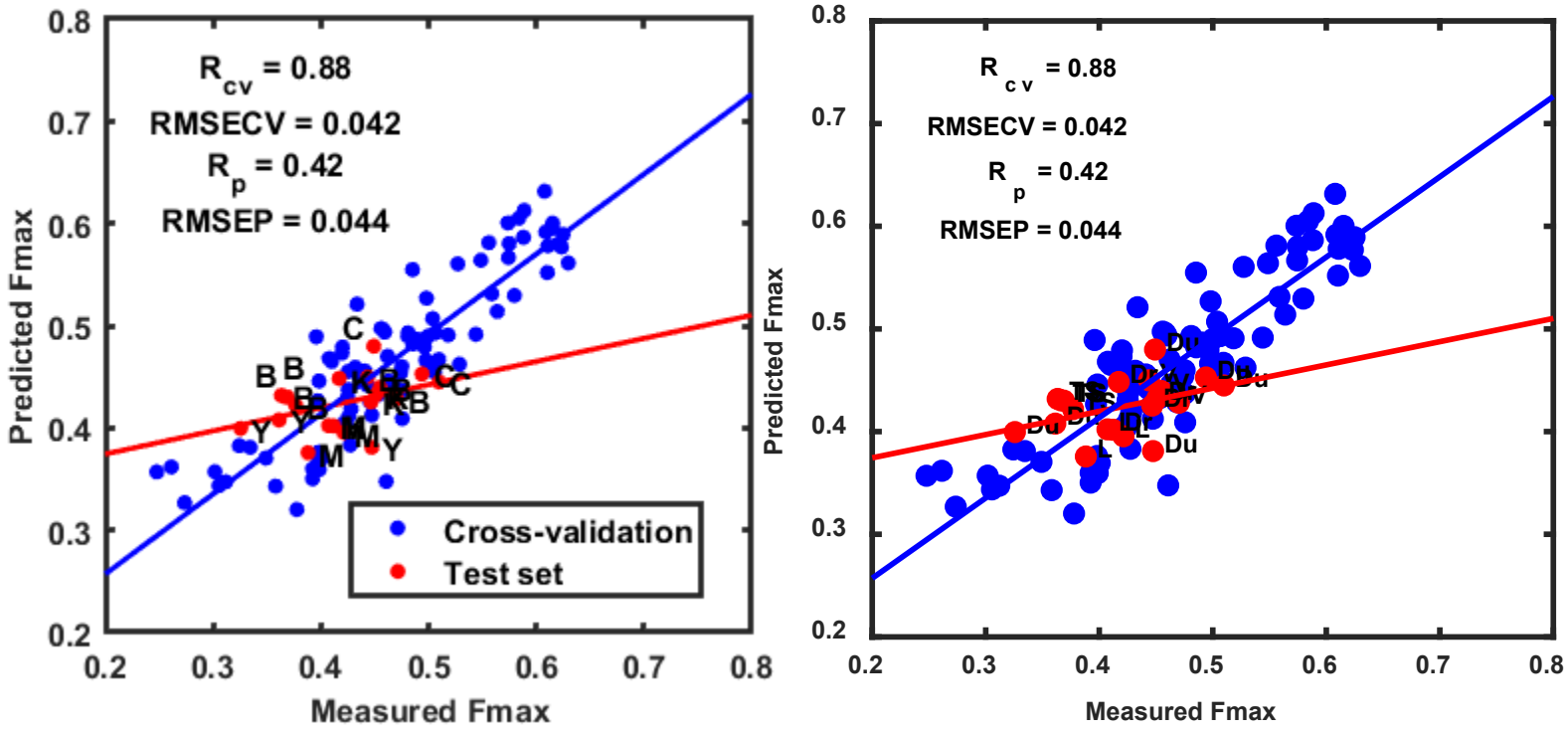
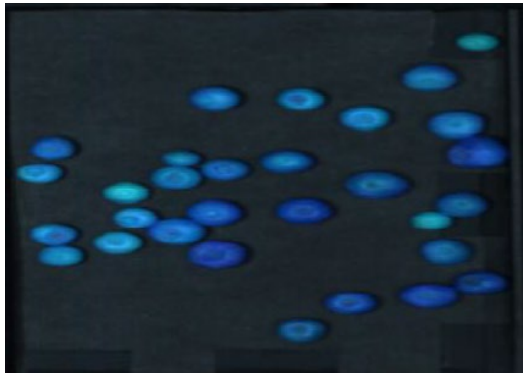
Model recalibrate with 4 samples measured on the black surface

Grower
Y = Yken
K = Koops
C = Criens
M = Magoley
B = Blueberry Garden



Cultivar
Du = Duke
Dr = Draper
L = Liberty
V = Valor
TS = Top Shelf



- The model bias is now removed
- Blue dots are the calibration model
- Red dots are the test set
- Prediction error (0.044) is higher than in the standard on side position and blue plate configuration (0.036)

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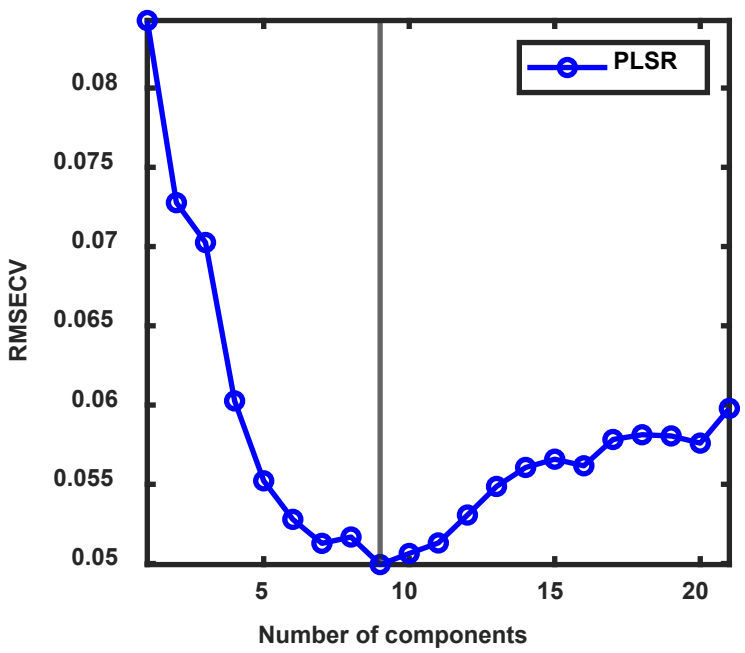
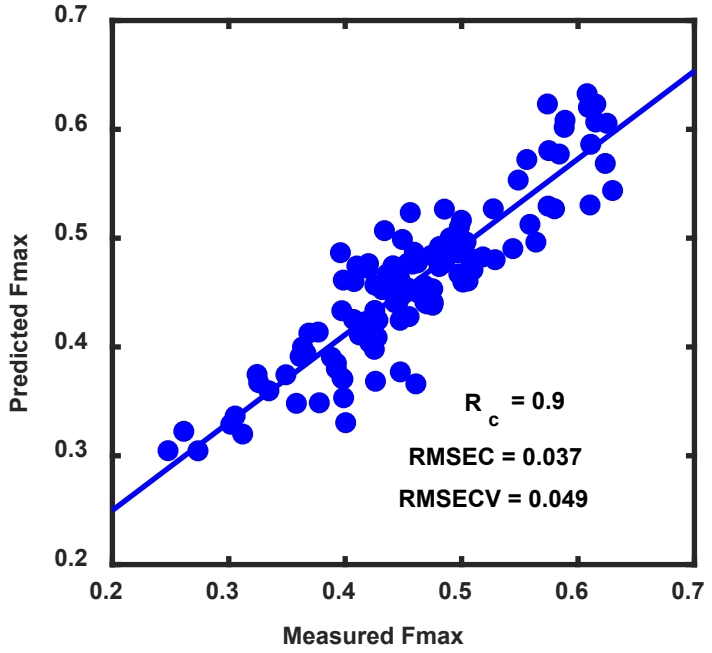
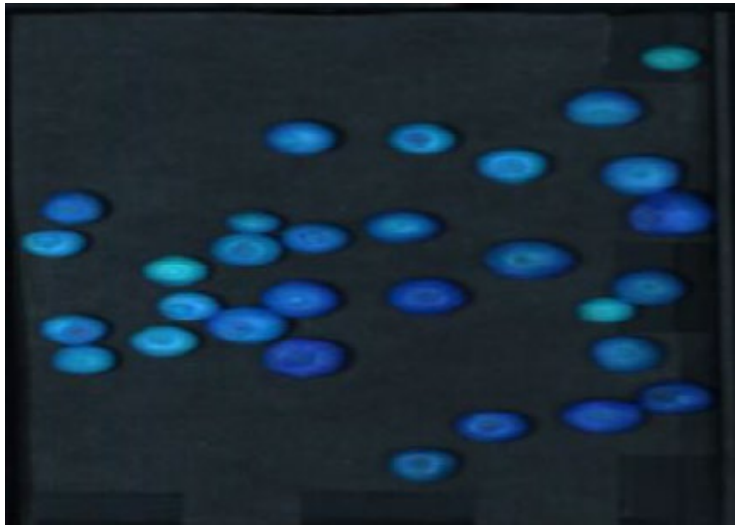
Final model to predict Fmax of blueberries on a black background/surface for practical implementation







- The final model that can be used to predict Fmax of blueberries rolled directly on a black background/surface
- The model is suitable for direct implementation in industrial applications

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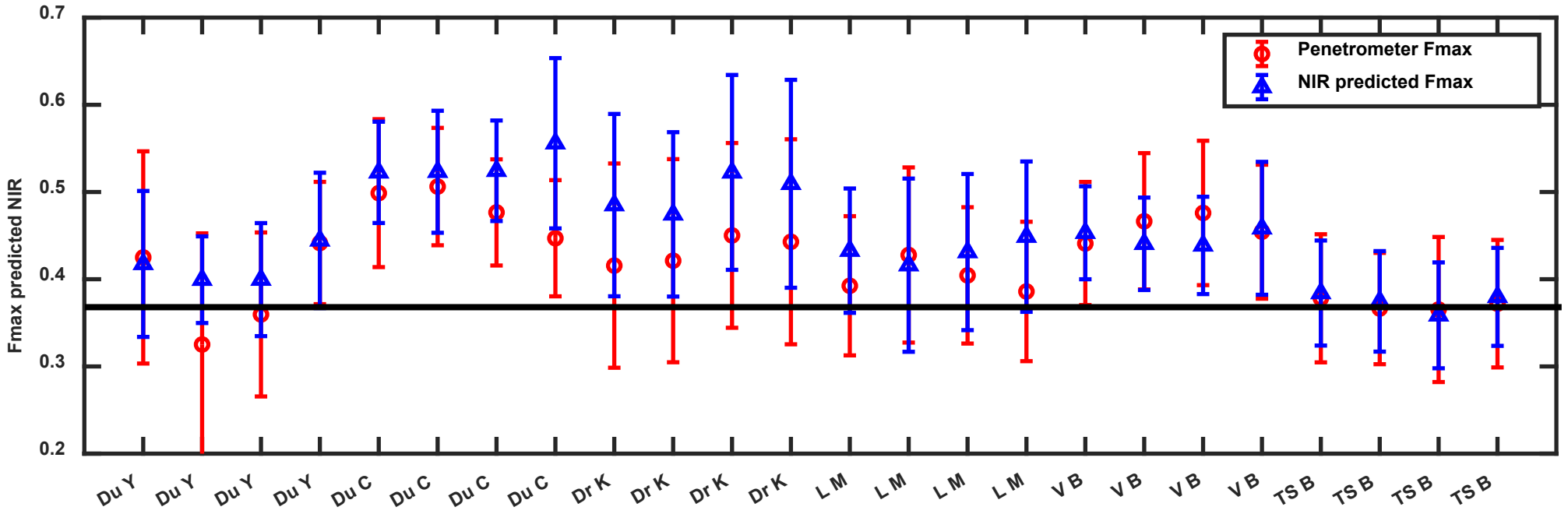
Quantification batch heterogeneity (next to average firmness)

- Graph shows average firmness and variation within each batch (the batches used as test set in the validation)
- In blue the average Fmax + variation in NIR prediction is given
- In red the average Fmax+ variation in corresponding Fmax measured with FTA is given

Cultivar
Du = Duke
Dr = Draper
L = Liberty
V = Valor
TS = Top Shelf

Grower
Y = Yken
K = Koops
C = Criens
M = Magoley
B = Blueberry Garden



Black line is acceptance level (Fmax = 0.37 kg is limit)

Link Fmax – Baxlo as international accepted assessment method for firmness blueberries

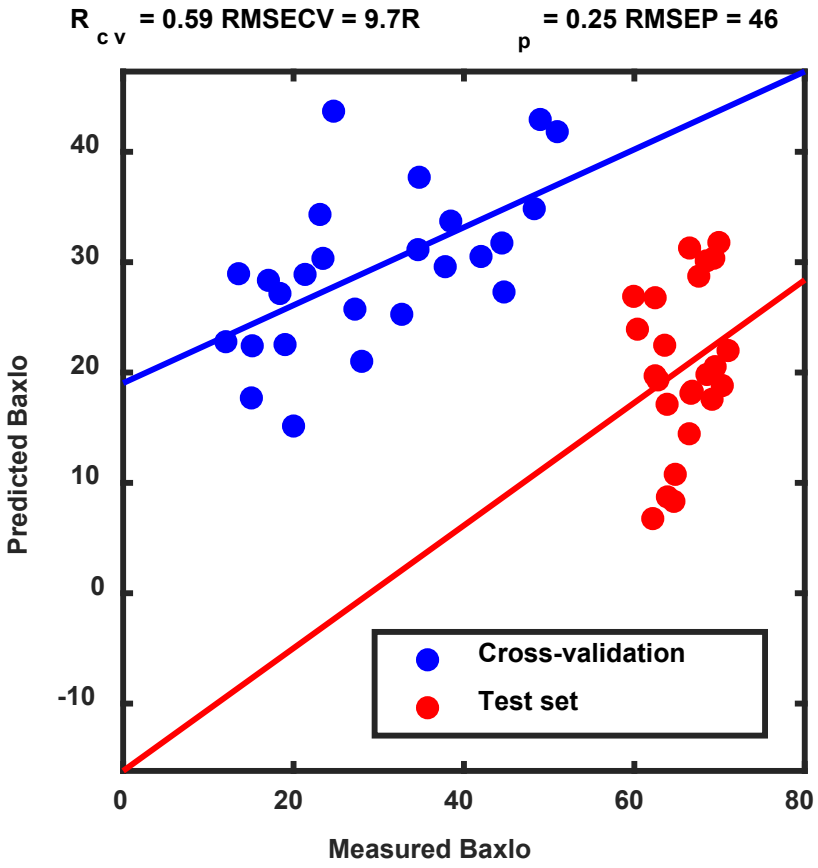
Baxlo is internationally accepted whereas Fmax not. The question is how can the Baxlo be linked to Fmax? How good is this relationship?

There are 2 approaches:

1. Measure berries with HSI model; use the obtained Fmax with a correlation Fmax-Baxlo to “translate” the Fmax in Baxlo
2. Development of HSI model with Baxlo

The first option adds up measurement errors; the second option is therefore preferred.

Calibration for Baxlo (punnet level)

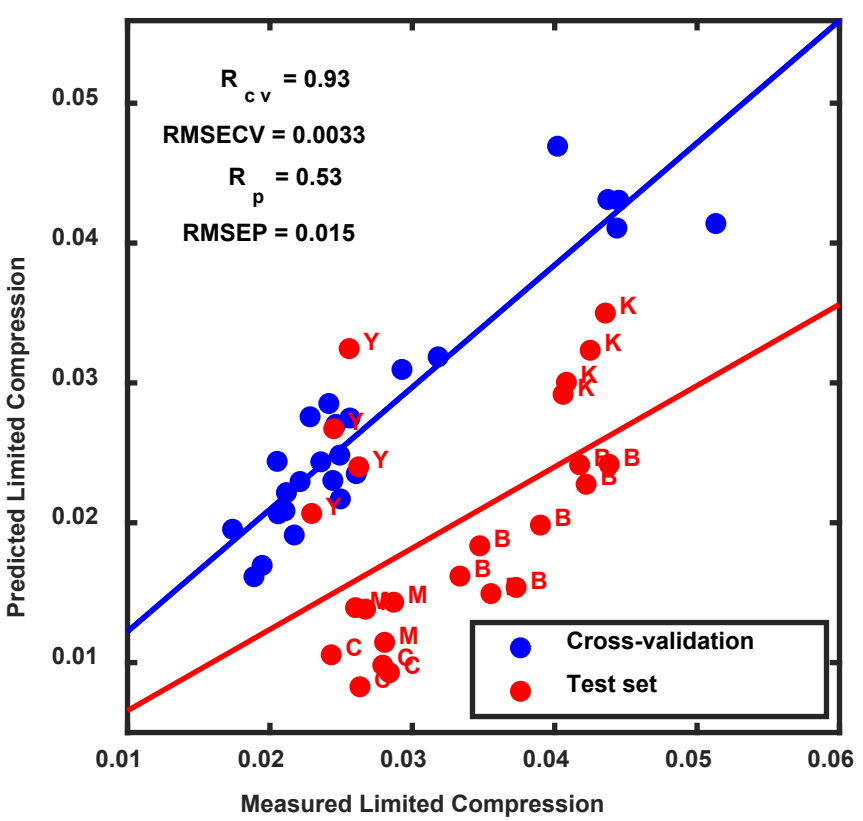


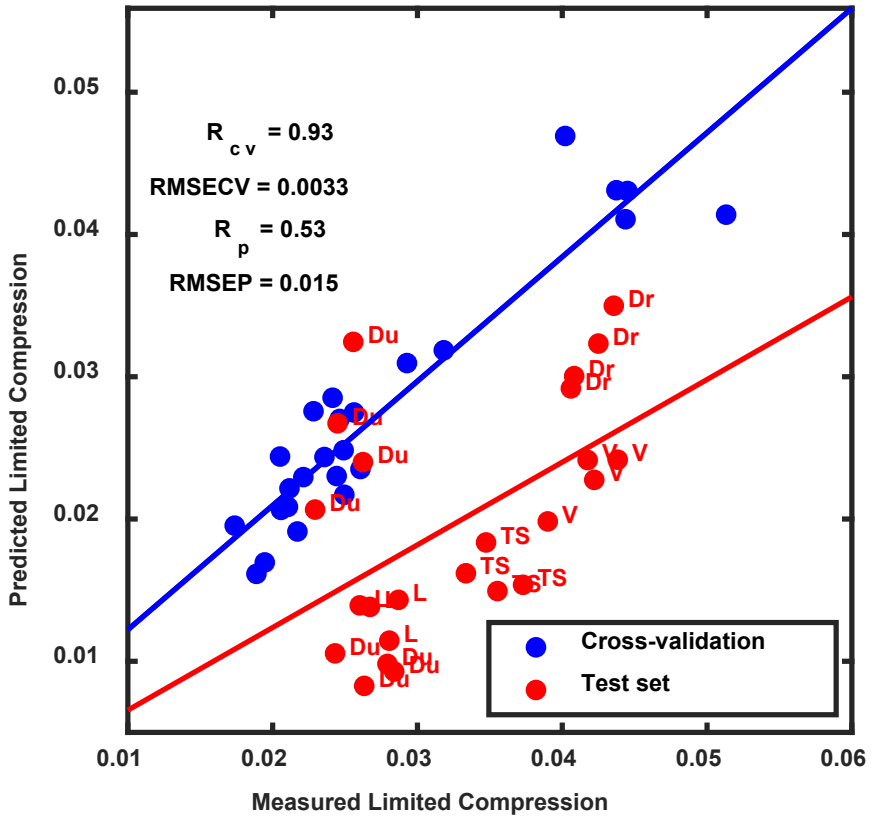
Prediction of Baxlo was difficult with NIR and poorer than predicting Fmax even at Punnet level

Calibration for limited compression (punnet level)

Model 2021 and test set consist of samples measured March 2022

Grower
Y = Yken
K = Koops
C = Criens
M = Magoley
B = Blueberry Garden





Cultivar
Du = Duke
Dr = Draper
L = Liberty
V = Valor
TS = Top Shelf

Limited Compression of samples was predicted well but mainly for Duke samples, for other the prediction were a bit biased

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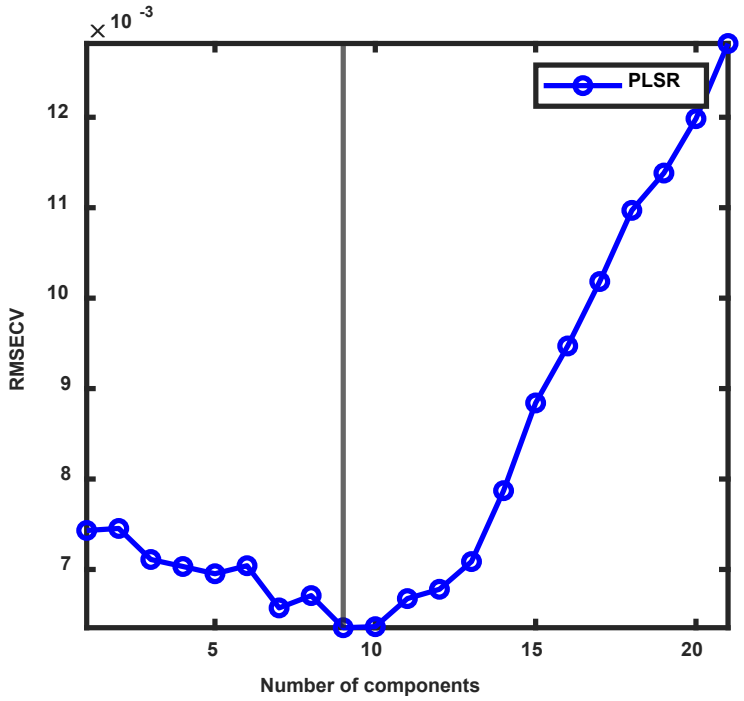
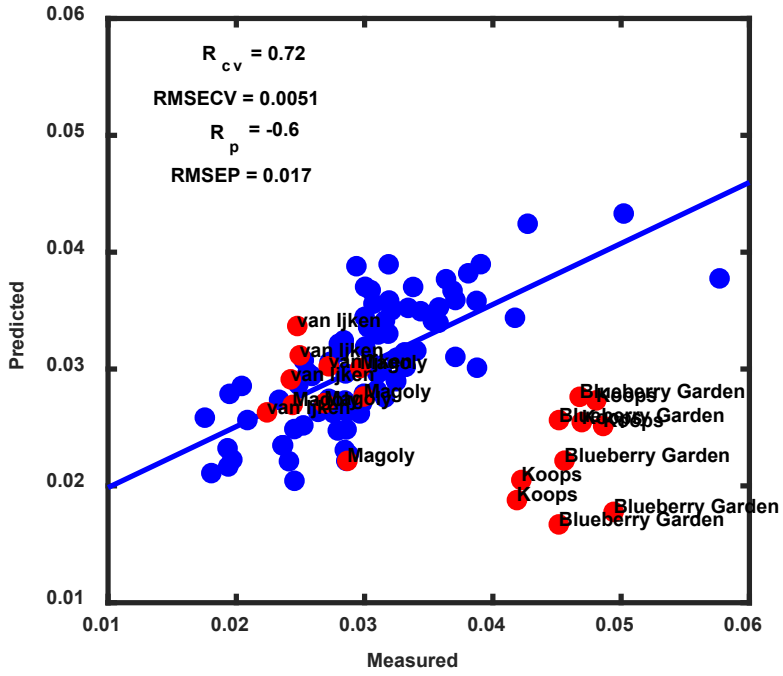
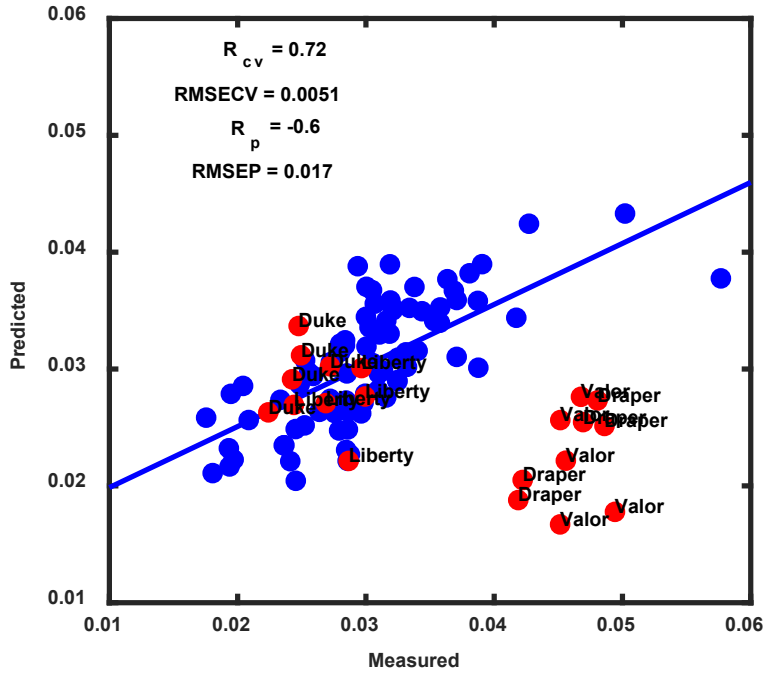
Analysis of Limited Compression







Duke and liberty were the main cultivars predicted in range other cultivars were biased.

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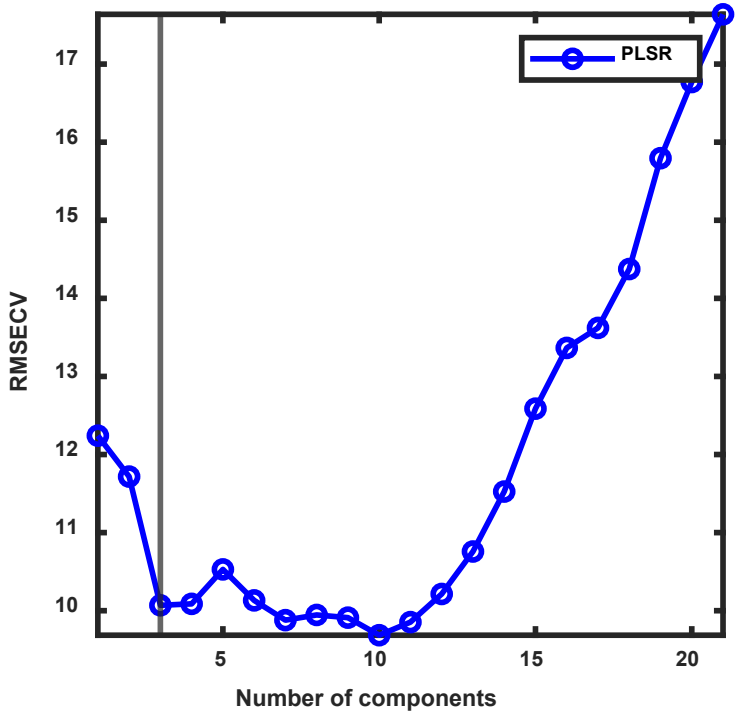
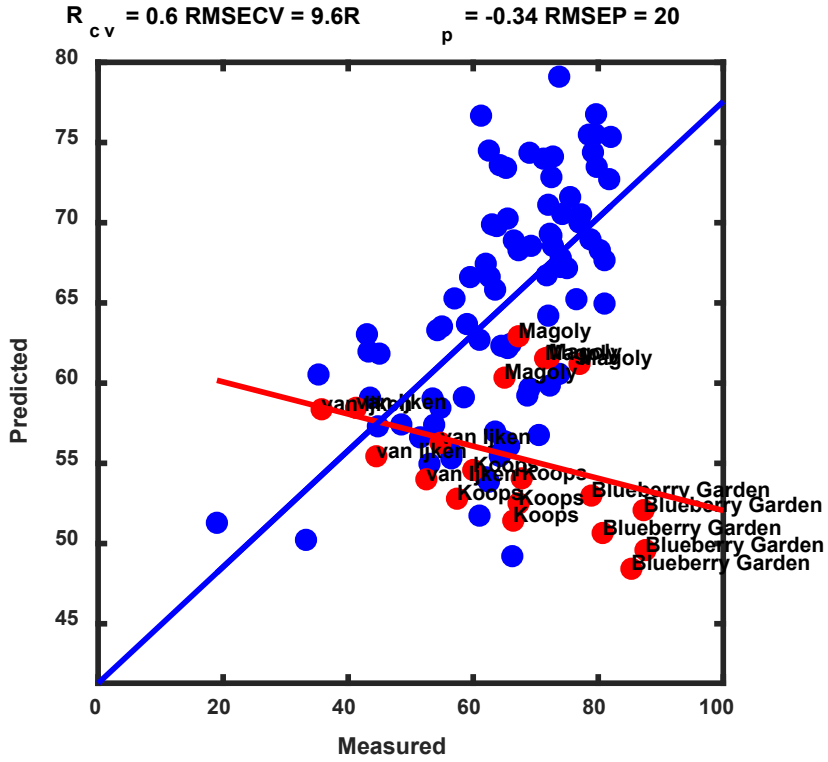
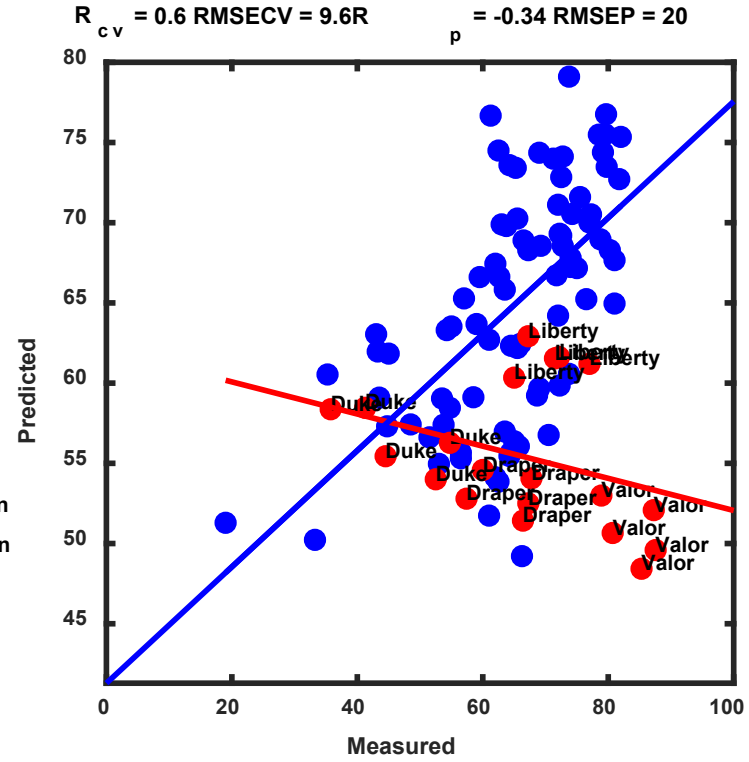
Model 2021 extended with samples measured March 2022; Test set consists of the samples measured in the summer 2022

Analysis of sensory data (Bloom)







Duke and liberty were the main cultivars predicted in range other cultivars were biased.

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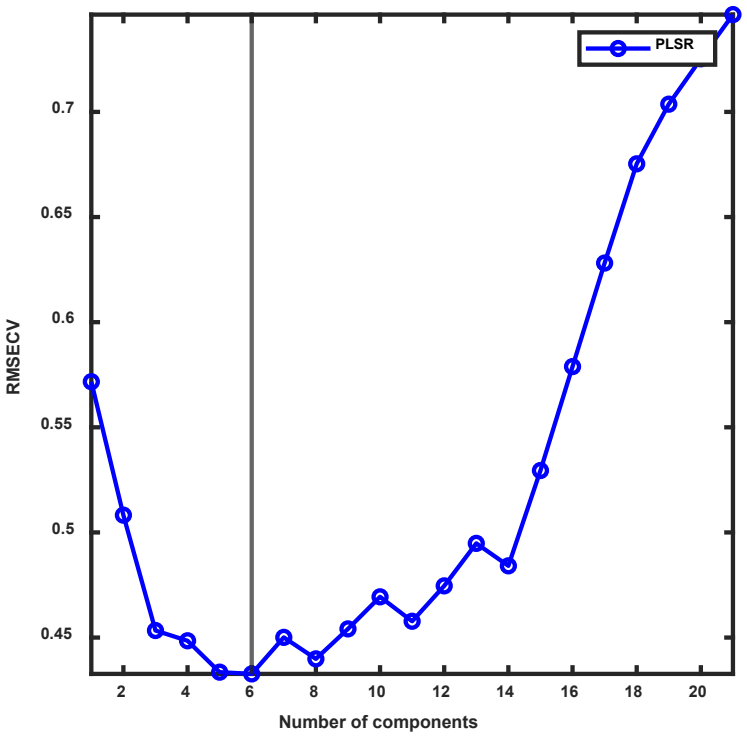
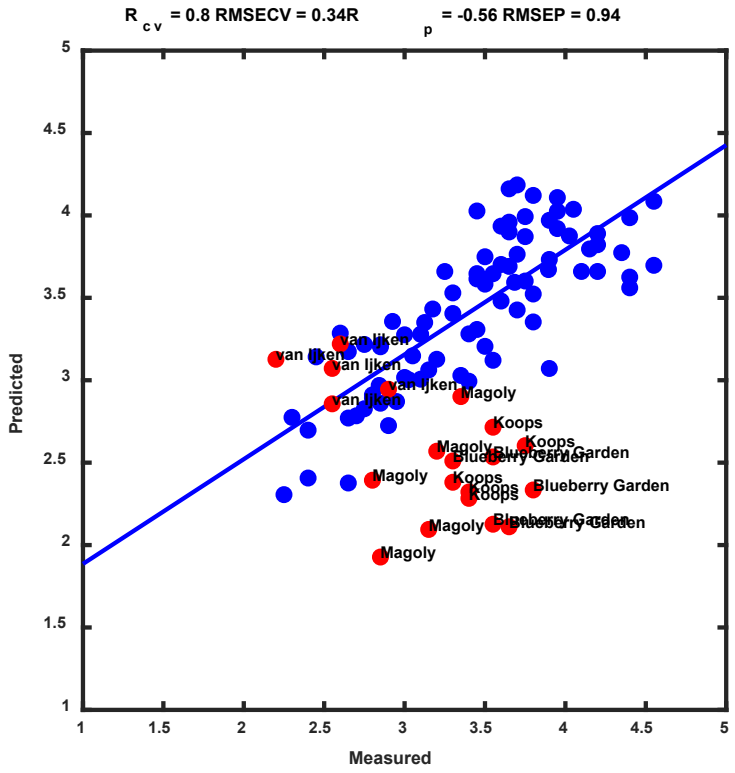
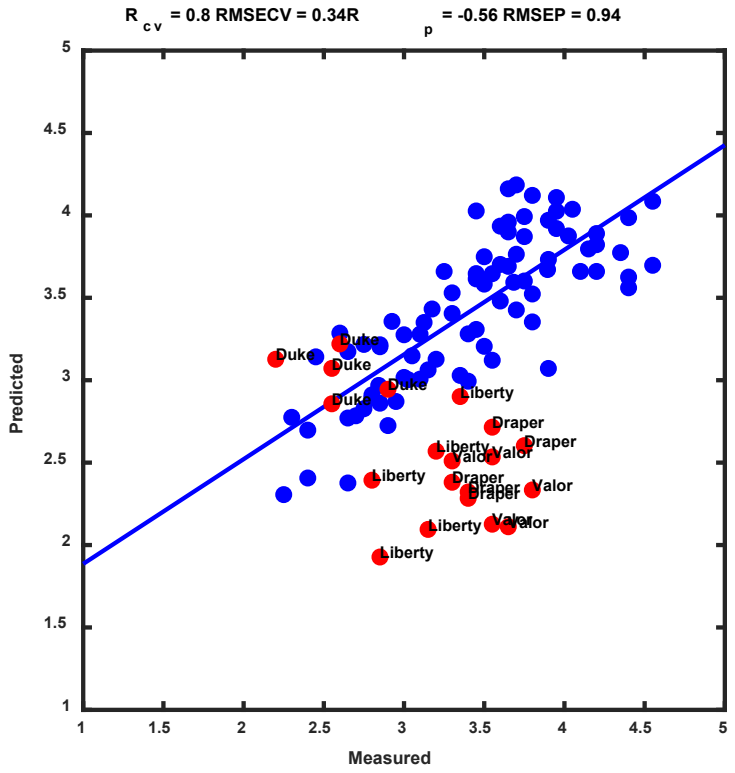
Model 2021 extended with samples measured March 2022; Test set consists of the samples measured in the summer 2022

Analysis of sensory data (Firmness)







Duke was the main cultivar predicted in range other cultivars were biased.

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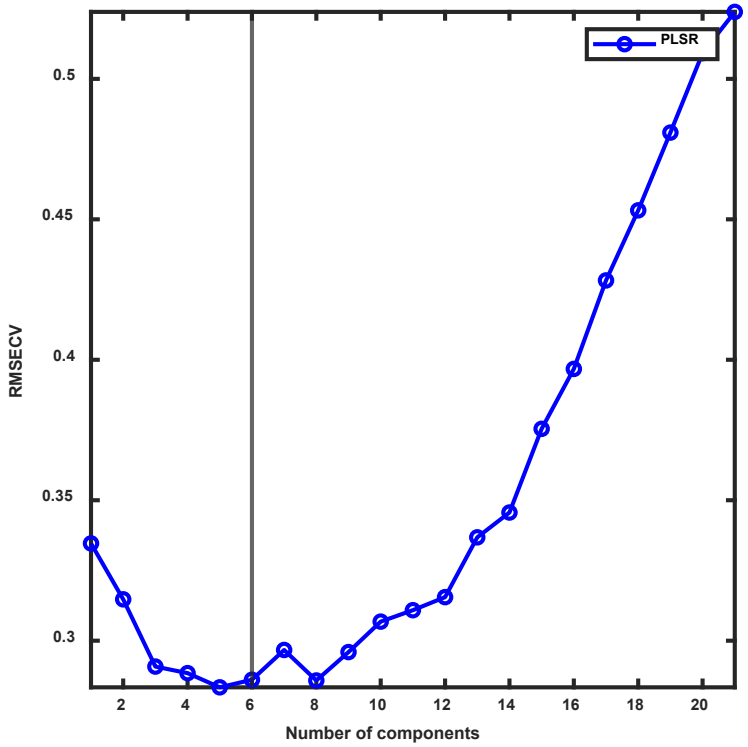
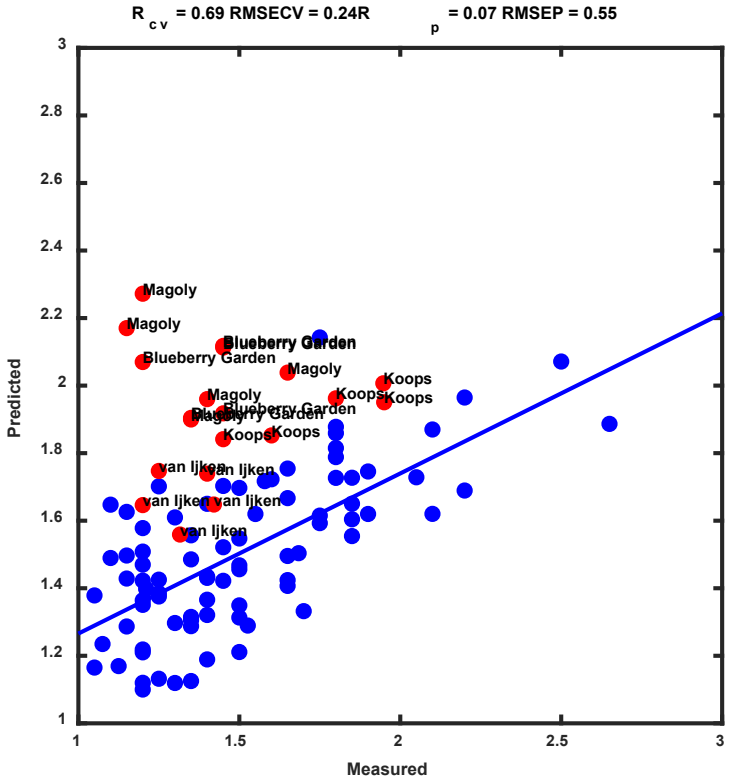
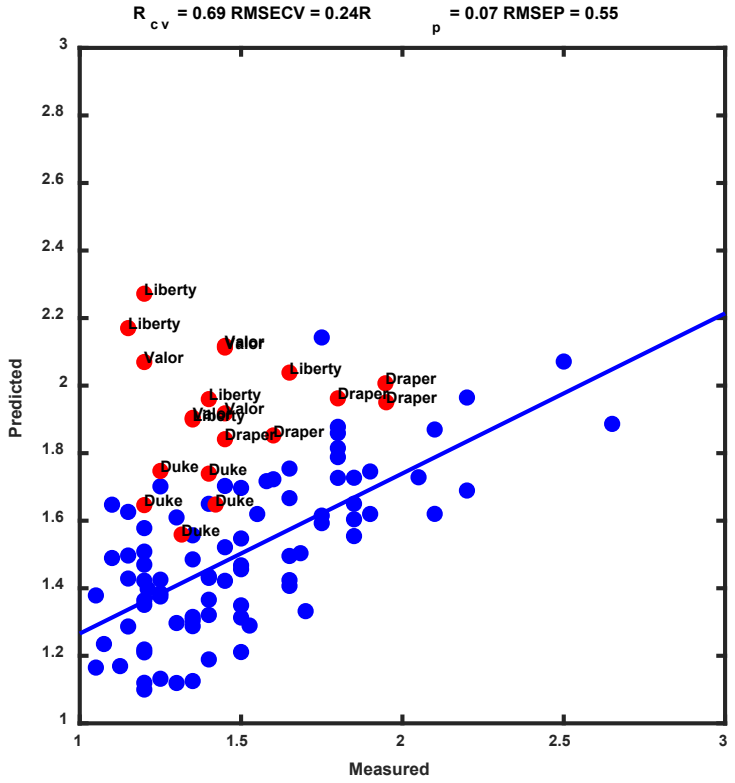
Model 2021 extended with samples measured March 2022; Test set consists of the samples measured in the summer 2022

Analysis of sensory data (Mealiness)







Duke was the main cultivar predicted in range other cultivars were biased.

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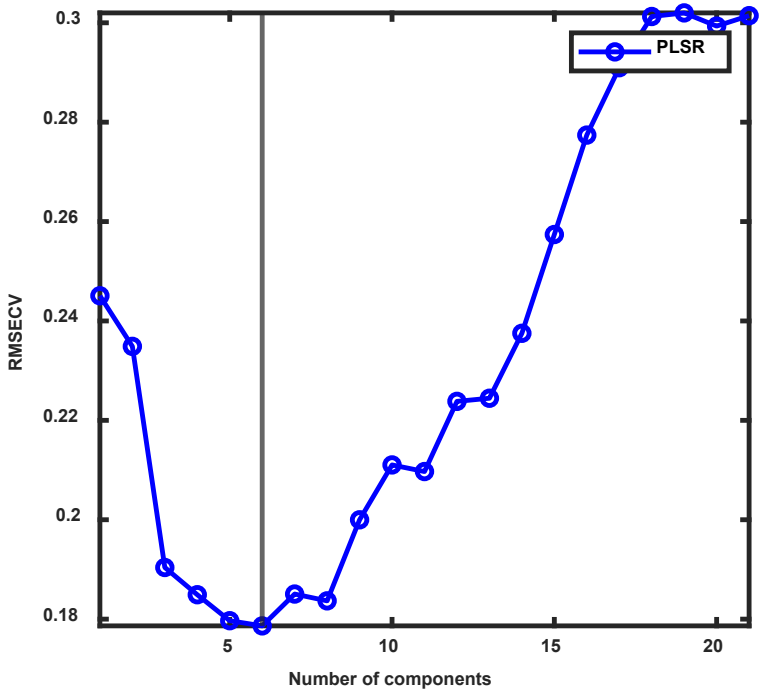
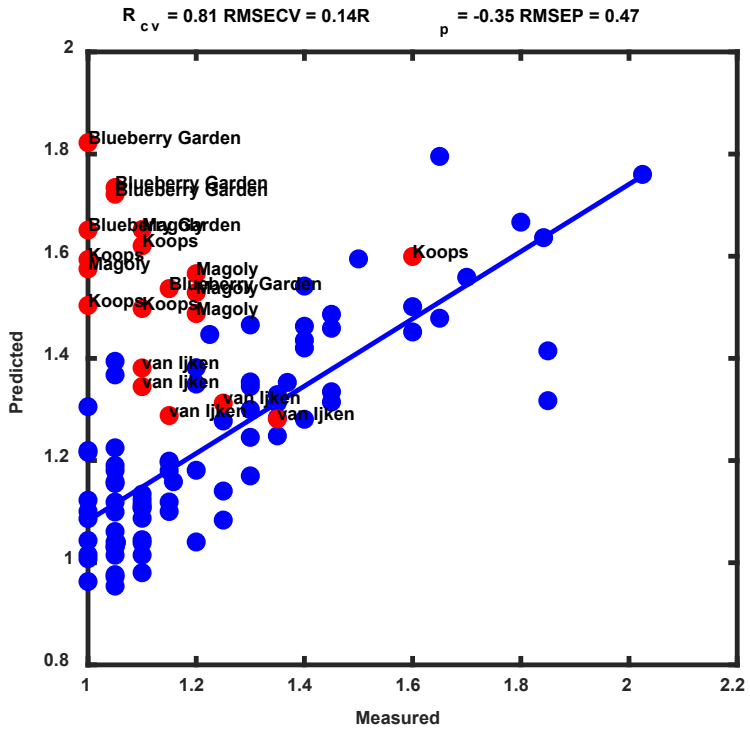
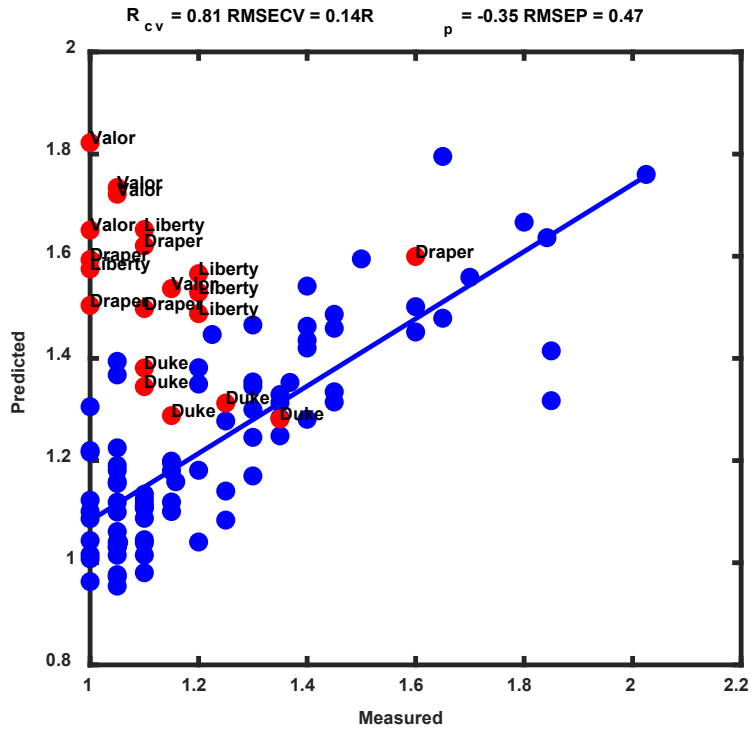
Model 2021 extended with samples measured March 2022; Test set consists of the samples measured in the summer 2022

Analysis of sensory data (Internal Breakdown)







Duke was the main cultivar predicted in range other cultivars were biased.

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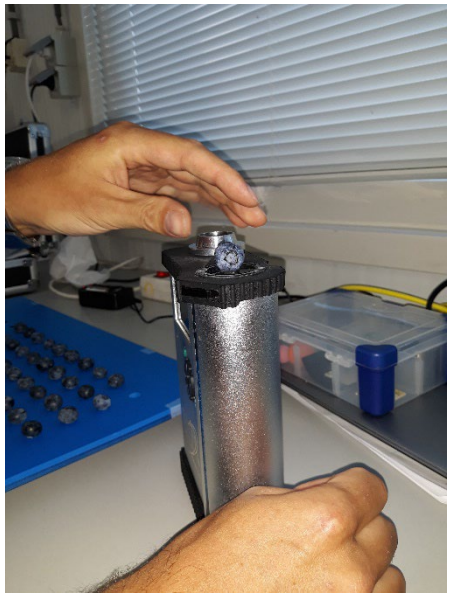
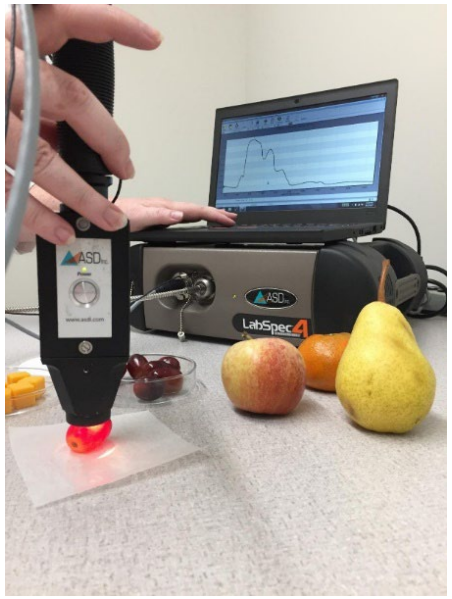
Model 2021 extended with samples measured March 2022; Test set consists of the samples measured in the summer 2022

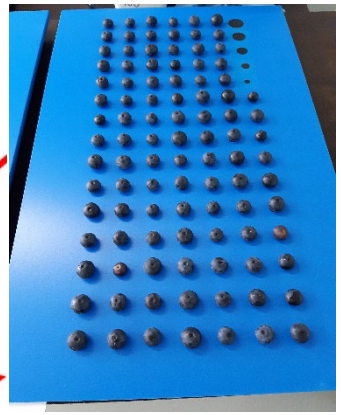
Content

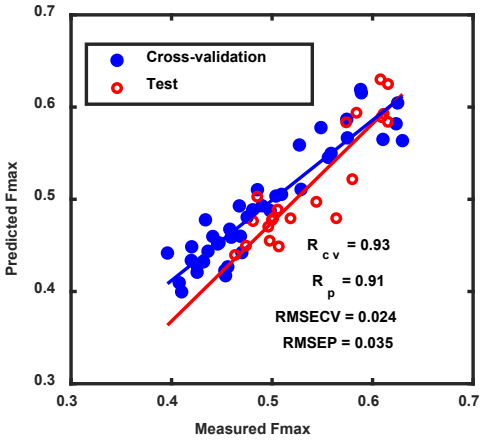
- Kick-off project
- First year– Focus mealiness (2019)
- Second year- Focus non-destructive texture method (2020)
- Third year– Improve texture method; Develop HSI assessment method (2021)
- Fourth year – Validation & company implementation (2022)
- **Final project conclusions**

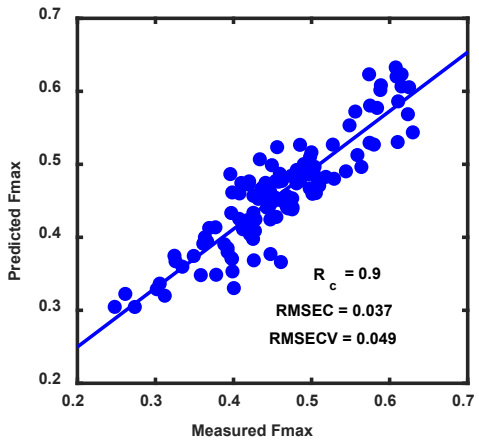
Final Conclusions Project











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Final Conclusions Project

- NIR model (HSI) is able to predict Fmax with RMSEP=0.036 Kg
- Different growers and different cultivars are rather well predicted -> HSI model seems robust!
- Implementation in industry is possible = placing berries randomly on plate -> loss of accuracy is limited
- It is also possible to measure direct on cabinet (black background)
- Model NIR – Baxlo: not good enough
- Model NIR - Limited compression: not as good as Fmax (less samples)
- Model NIR – sensorial parameters: less robust, maybe suitable to identify extreme batches.

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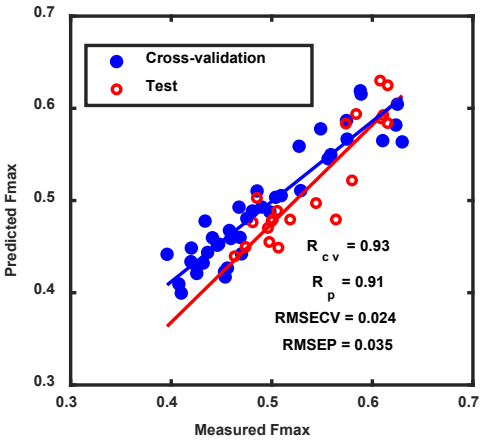
Final Conclusions Project

- Baxlo and Turoni show correlations with Fmax, Limited compression and Firmness score on punnet level (slide 78)

- Baxlo measurements in 2022 better (new device!)

- Sample size: 100 berries per batch is more than enough



- Accuracy Fmax defined: ±0.07 kg; RMSEP (0.035 kg) of the HSI model is lower than the required accuracy.

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Non-destructive firmness assessment: Future view

- Integration of the model in the hyperspectral cabinet
    - Automatically identify each berry image
    - Software to run model and provide average + variance each batch
- Maintenance will be needed time to time
- Upgrade to other cultivars

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Thank you for the collaboration!