Leibniz Gemeinschaft

Modelling the shelf life of fruit depending on pre-harvest and post-harvest conditions

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ColdChain 2008, Bonn

Fruit and vegetable supply chain

Big demand of all players in the fruit and vegetables supply chain to get online information on every step in the chain:

Producer: produce, pre harvest parameters (i.e. plant protection), produce quality, time, temperature at and after harvest …

Transport: Time, temperature, rh ..

Farm coop.: + storage conditions, packaging, time, temperature, rel. humidity …

Transport:

Wholesale: + time, temperature, rel. humidity …

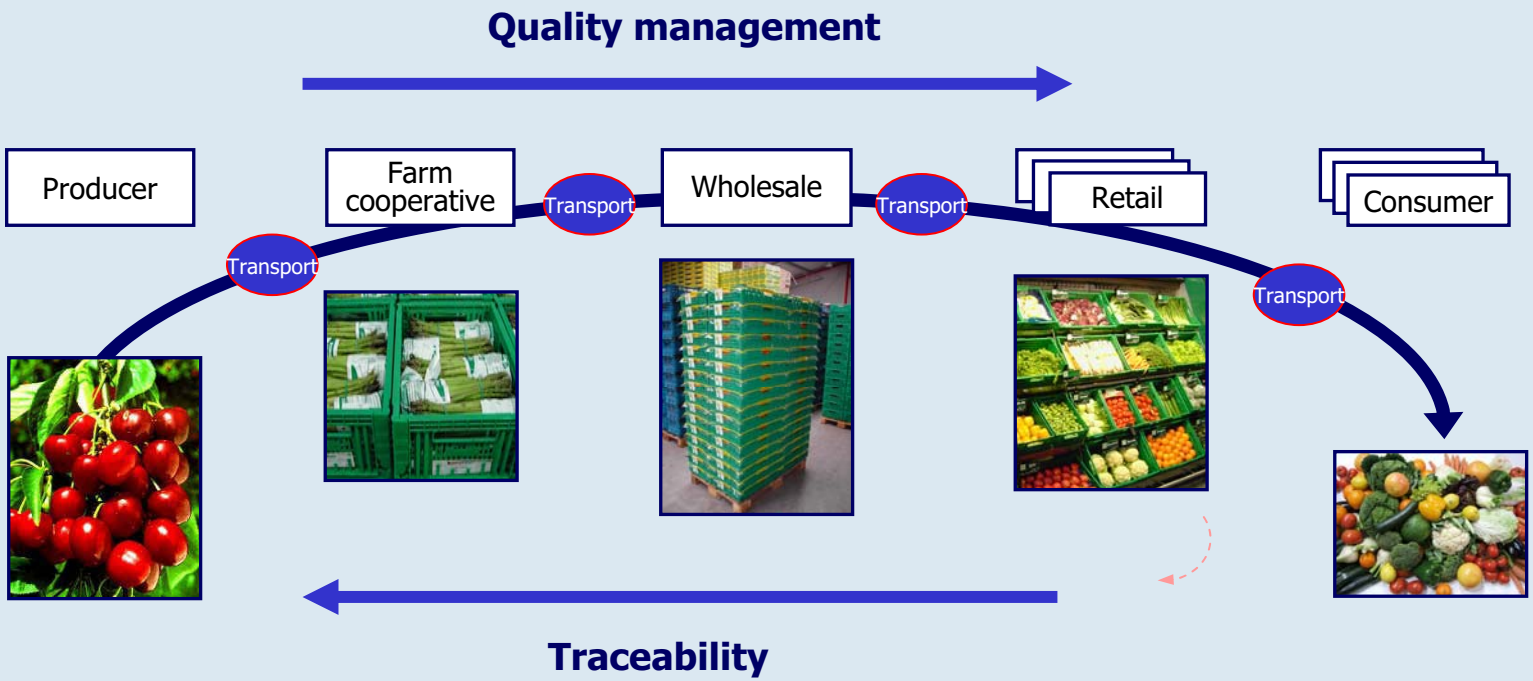
Transport:

Retail: + time, temperature, rel. humidity …

Transport:

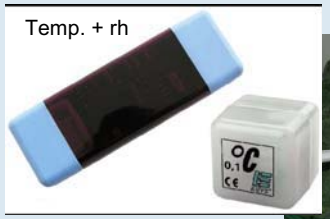
Consumer: ??

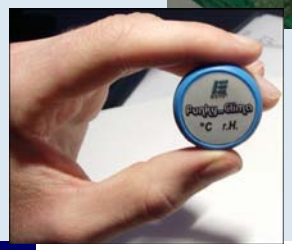
Modelling the shelf life of fruit depending on pre-harvest and post-harvest conditions



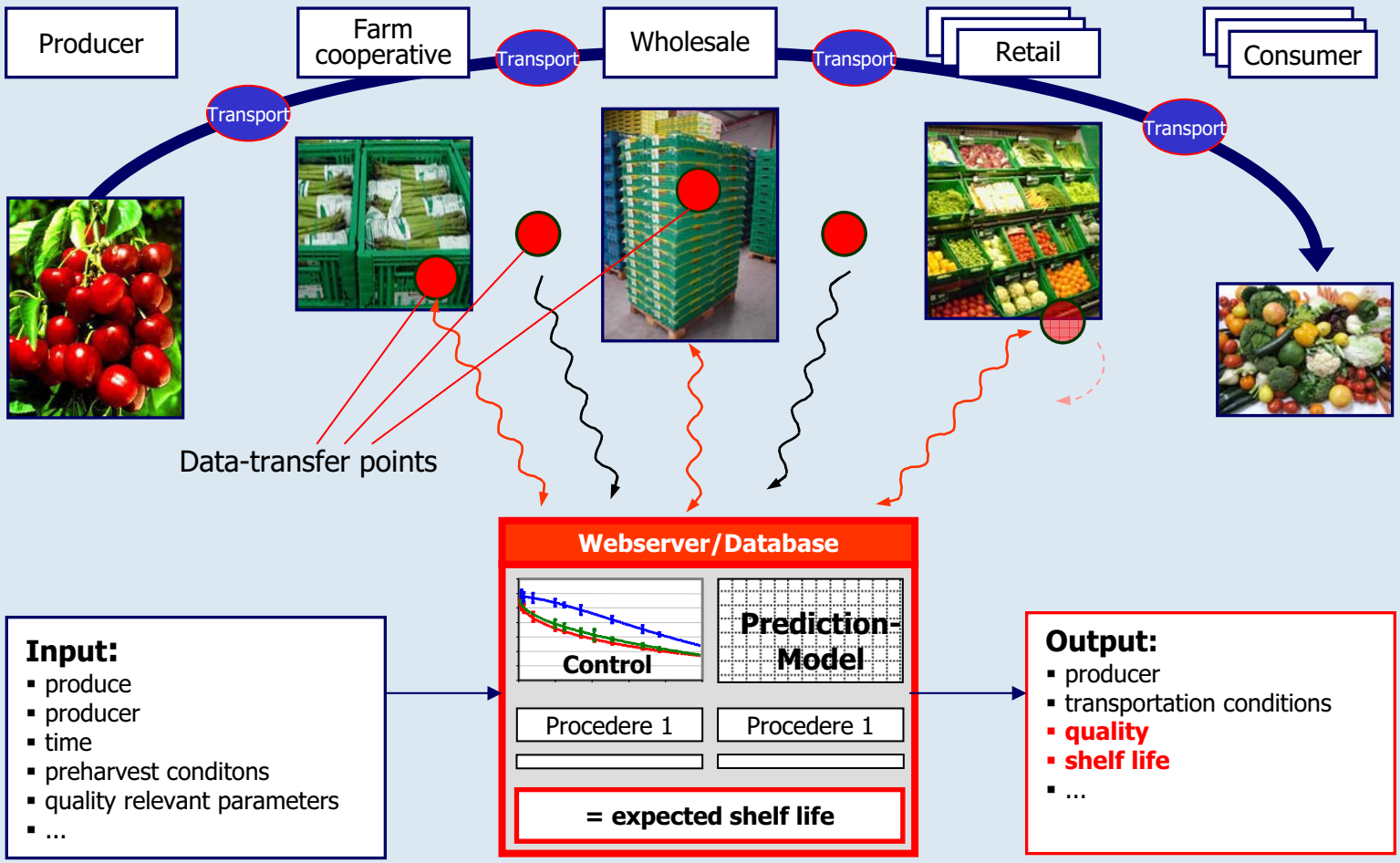
Wireless datalogger fitted with shelf life prediction model

- line-of-sight is not required
- rapid and simultaneous reading of tags resp. logger
- larger data storage capacity
- real-time information updates along the supply chain
- integration of sensors





Monitoring the Environmental Conditions during Transport and Distribution and Predicting the Shelf Life



Predicting the Shelf Life based on Thresholds of Marketability

Consumer Preferences: **visual** [color, brightness, intactness, shape....]

(EU Norms) **olfactory** [smell, ...]

tactile [consistency, elasticity, stiffness....]

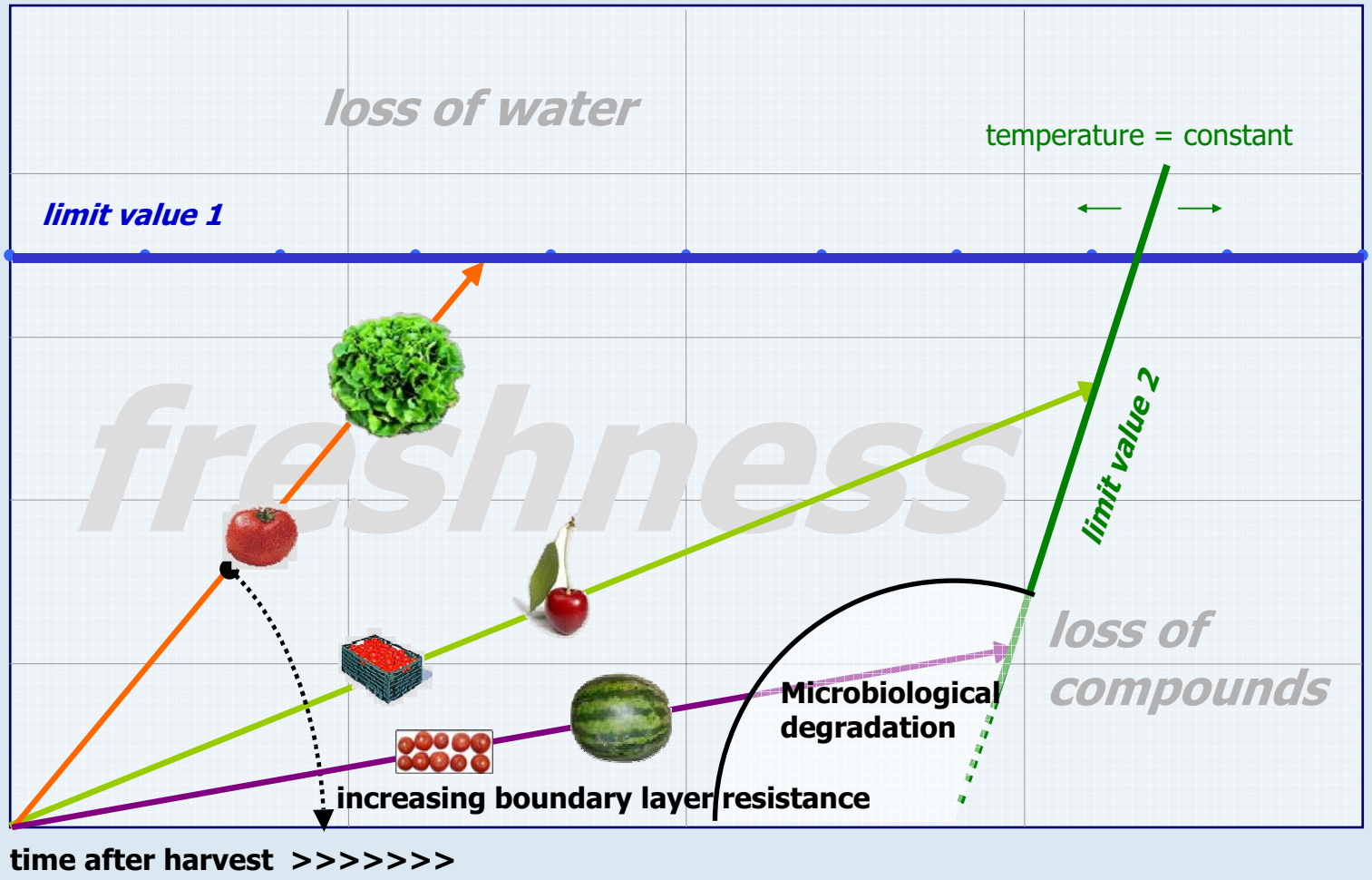
gustatory [taste, (texture), ...]

Properties and Processes: **compounds** [pigments, volatile components, acid, SSC, lipids, ...]

metabolism [transpiration, respiration, degradation, transformation....]

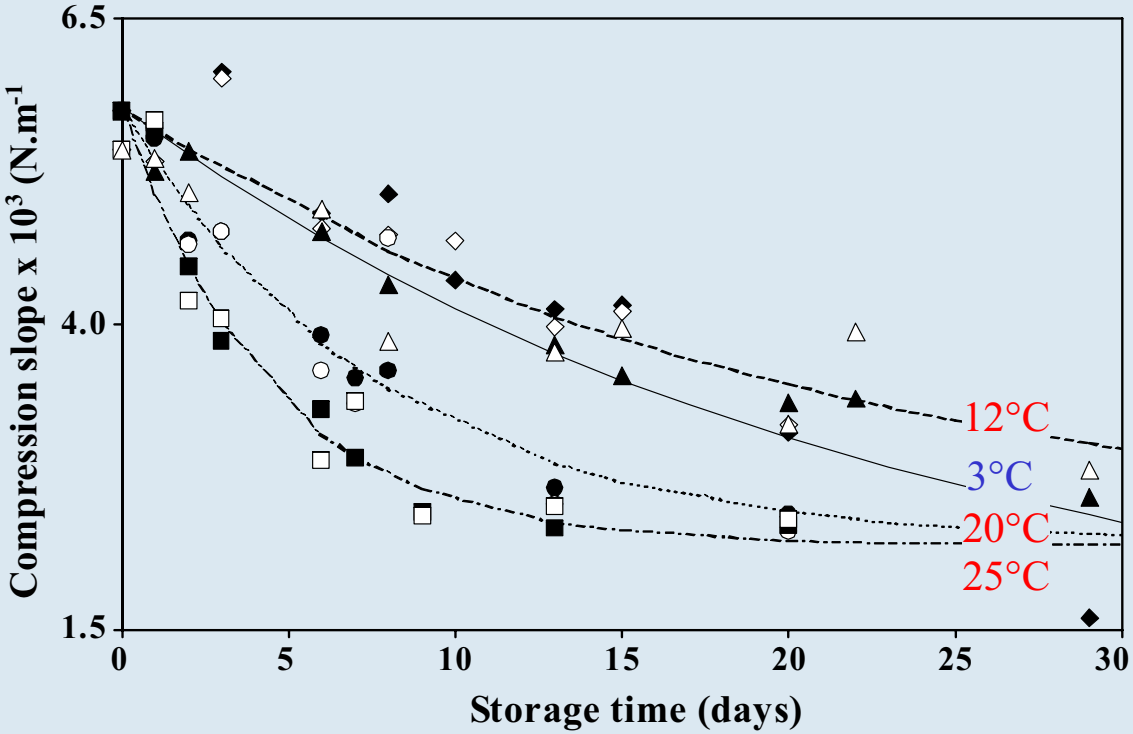
Threshold of marketability for tomato: stiffness

Predicting the Shelf Life based on Thresholds of Marketability



Modelling the Stiffness of Tomato

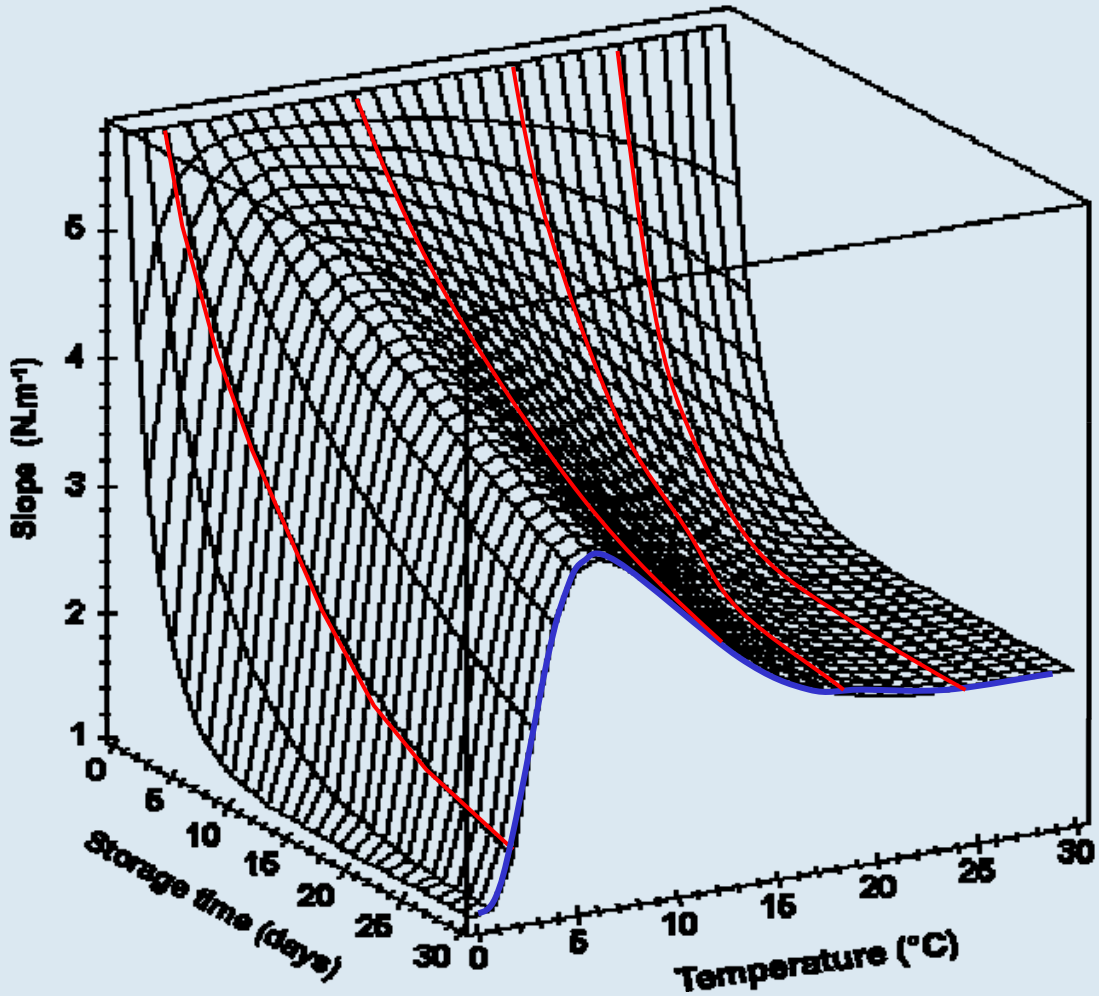
Thermal impact [C. VAN DIJK (2006)]



Effect of storage time and temperature on the firmness of tomatoes at 3°C; 12°C; 20°C and 25°C

Modelling the Stiffness of Tomato

Thermal impact [C. VAN DIJK (2006)]

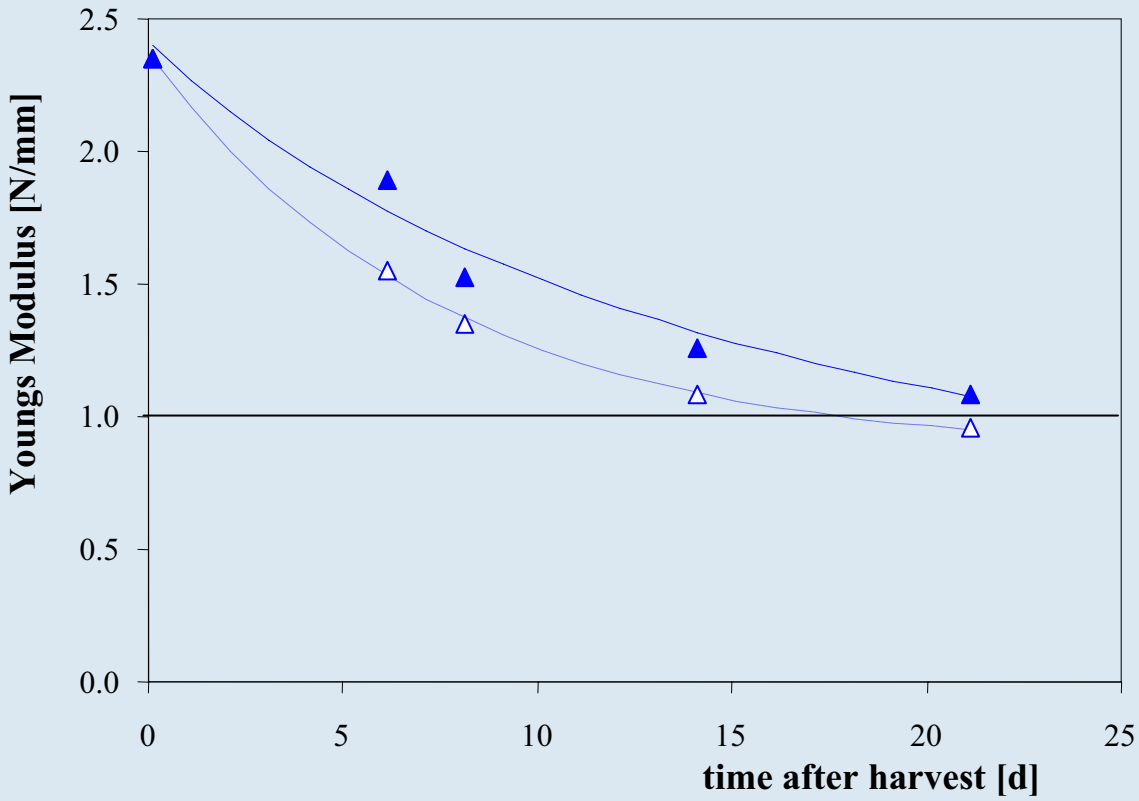


Modelling the Stiffness of Tomato

cultivar '*Counter*'						
n=	432					
preharvest conditions	4 (salinity EC 2 resp. 9, CO_2 400 resp. 1000ppm)					
packaging	closed package (cp)			open package (op)		
storage temperature [°C]	10	15	20	10	15	20
storage humidity [%]	98	98	98	78	45	43
water **v**apour partial **p**ressure **d**ifference [hPa]	0.25	0.34	0.47	2.7	9.01	13.3
expert panel						
n_{tomato}=	40					
$N_{panelist}$=	30					
threshold of marketability (Young's Modulus [Nmm^{-1}])	1 **(sphere 7mm, N_{max} 3N)**					

Modelling the Stiffness of Tomato

Thermal impact



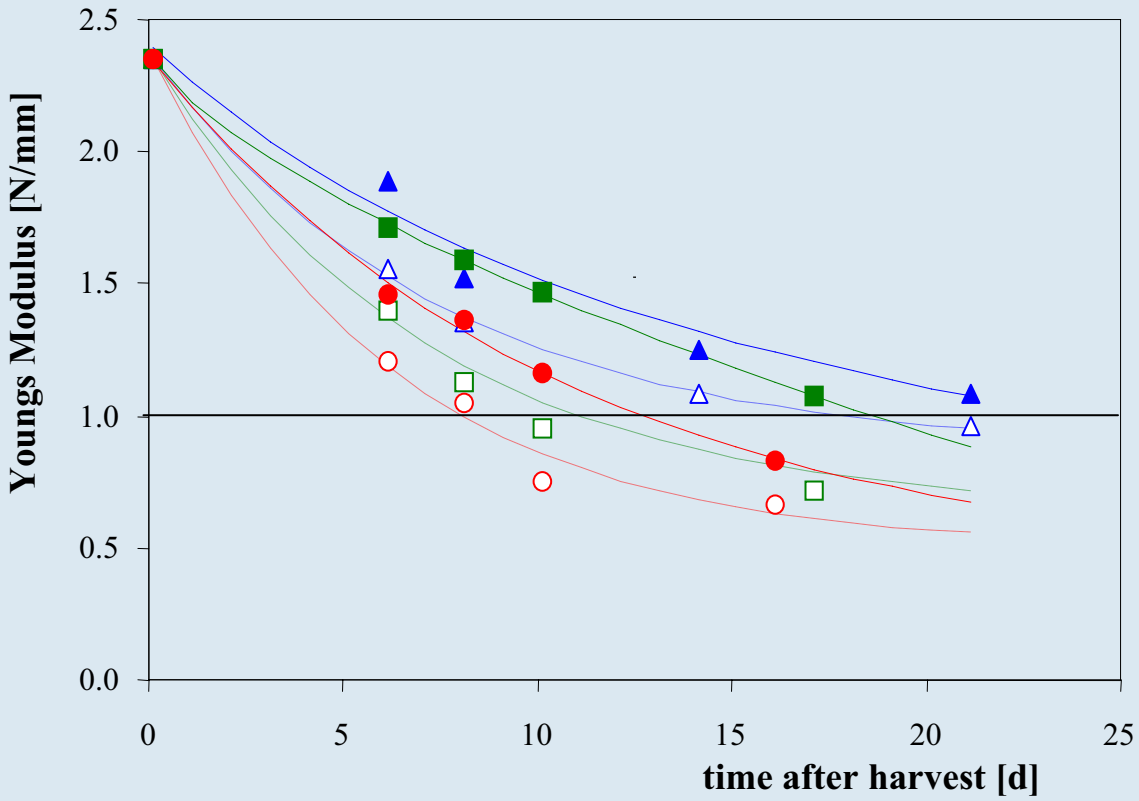
preharvest condition 2/400
initial stiffness ~ 2.5Nmm^{-1}
YM = f(t) Adj R^2~0.95

▲ 10°C_cp

△ 10°C_op

Modelling the Stiffness of Tomato

Thermal Impact

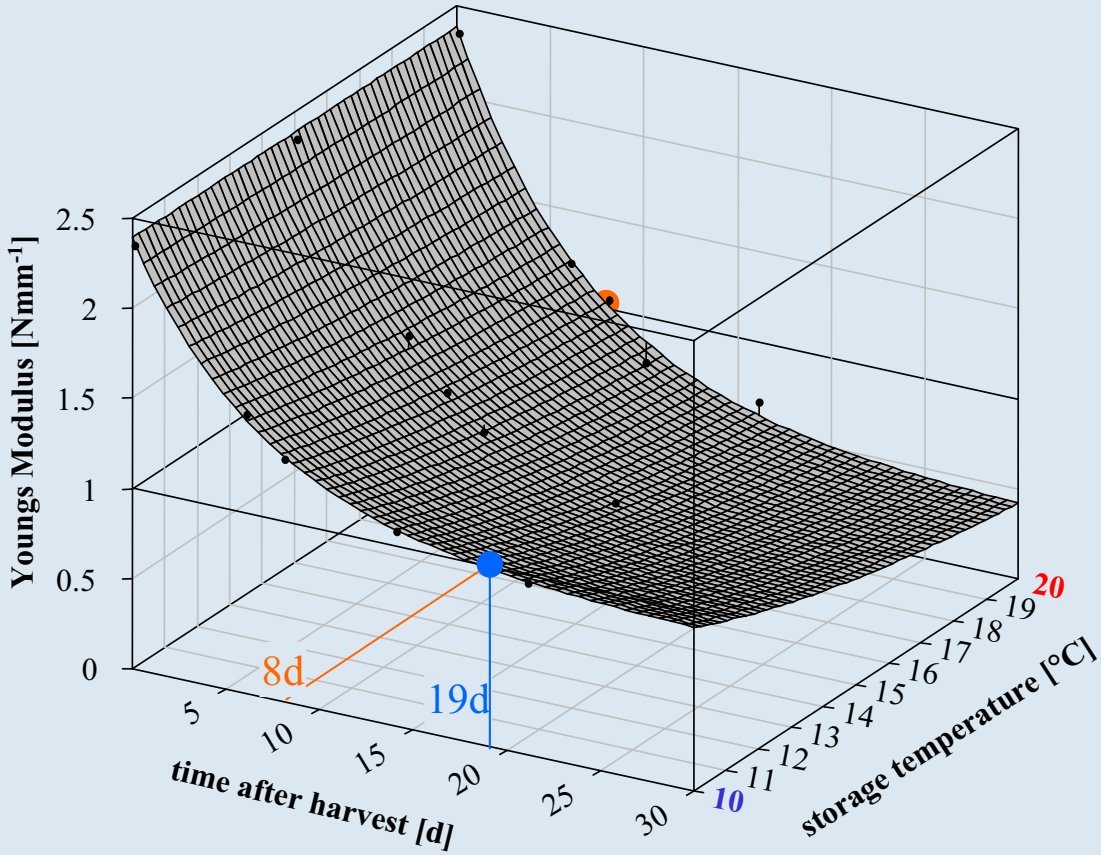


preharvest condition 2/400
initial stiffness ~ 2.5Nmm^{-1}
YM = f(t) Adj R^2~0.95

- ▲ 10°C_cp
- △ 10°C_op
- ■ 15°C_cp
- □ 15°C_op
- ● 20°C_cp
- ○ 20°C_op

Modelling the Stiffness of Tomato

Thermal Impact

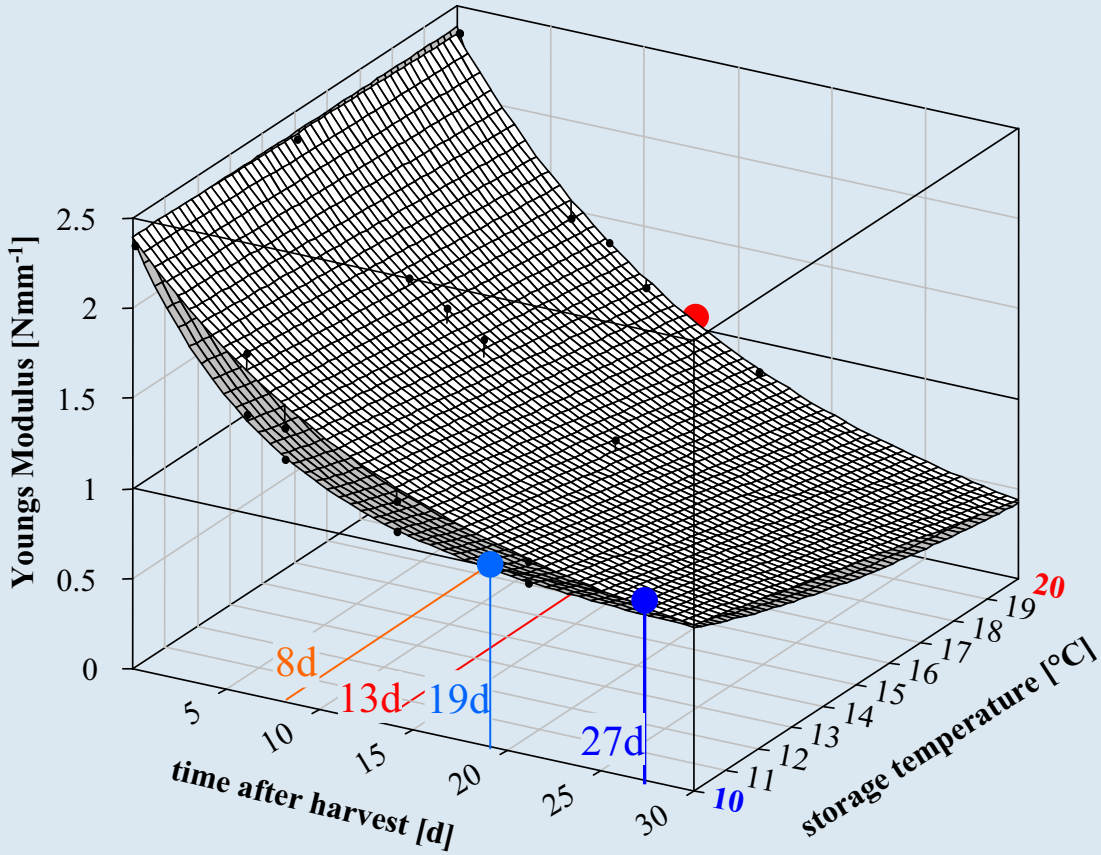


preharvest condition 2/400
initial stiffness ~ 2.5Nmm^{-1}
YM = f(t;T)

op Adj R^2=0.99
(8d to 19 d)

Modelling the Stiffness of Tomato

Thermal Impact + Effect of Water Regime



preharvest condition 2/400
initial stiffness ~ 2.5Nmm^{-1}
YM = f(t;T)

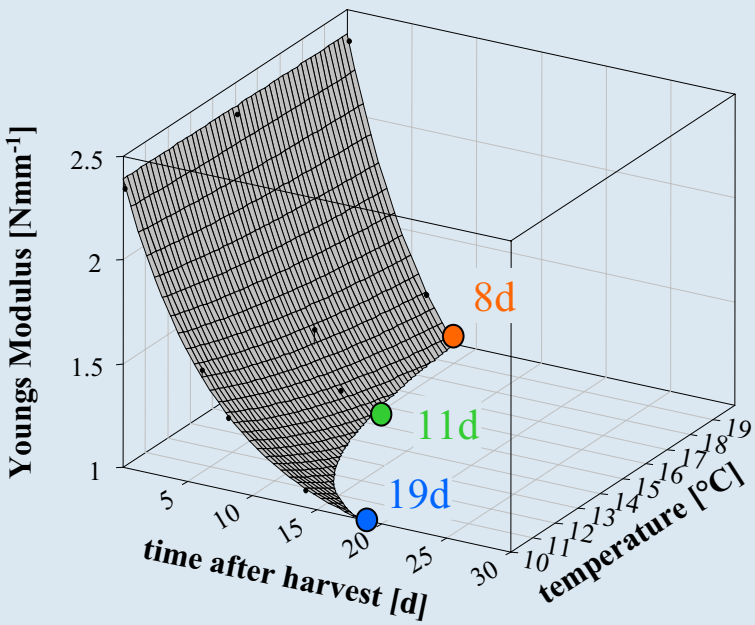
op Adj R^2=0.99
(8d to 19 d)

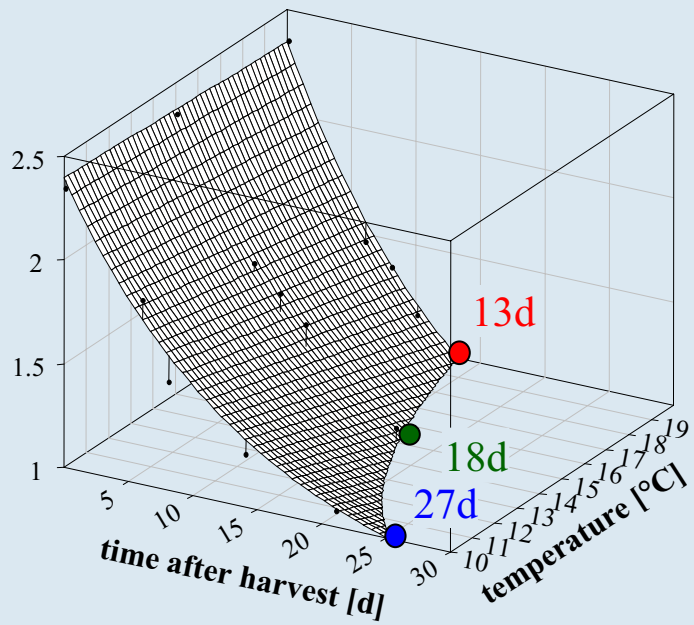
cp Adj R^2=0.96
(13 d to 27 d)

Modelling the Stiffness of Tomato

Thermal Impact + Effect of Water Regime

preharvest condition 2/400
initial stiffness ~ 2.5Nmm^{-1}
YM = f(t;T)





Modelling the Stiffness of Tomato

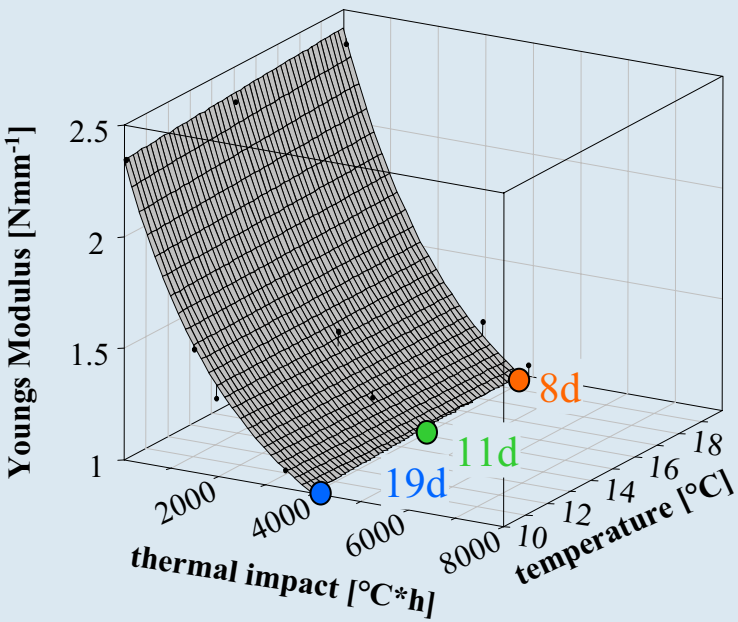
Thermal Impact + Effect of Water Regime

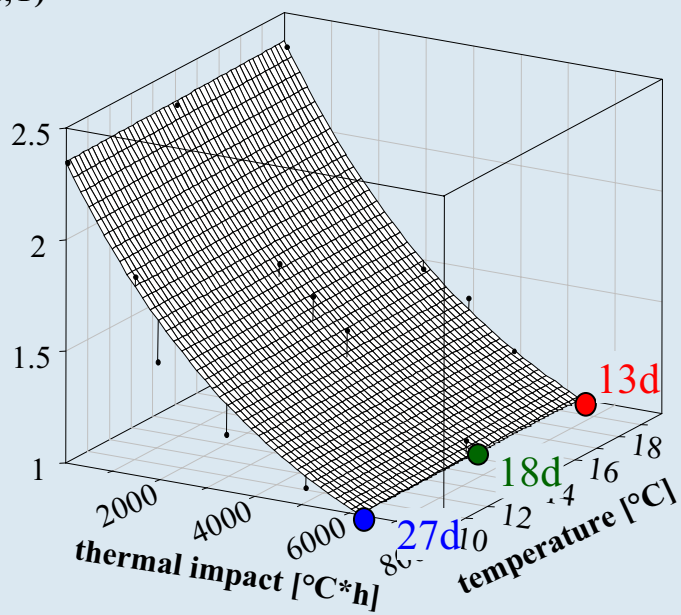
packaging	closed package (cp)			open package (op)		
storage temperature [°C]	10	15	20	10	15	20
thermal impact [°C*h] condition 2/400	**6480**	**6480**	**6240**	**4560**	**3960**	**3840**

op Adj R^2=0.98

preharvest condition 2/400
initial stiffness ~ 2.5Nmm^{-1}
YM = f(t;T)

cp Adj R^2=0.94

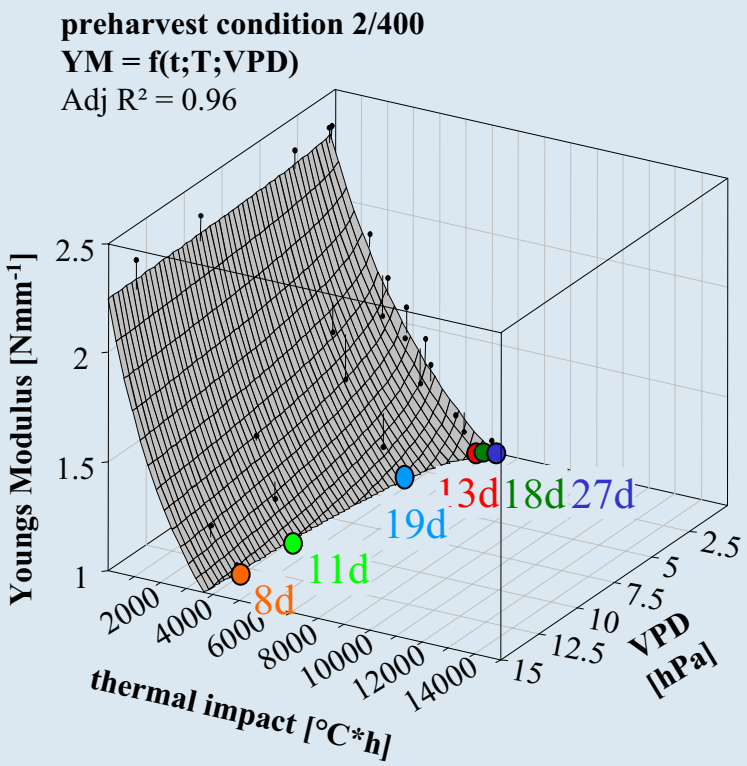




Modelling the Stiffness of Tomato

Thermal Impact + Effect of Water Regime [VPD=f(t;rH)]

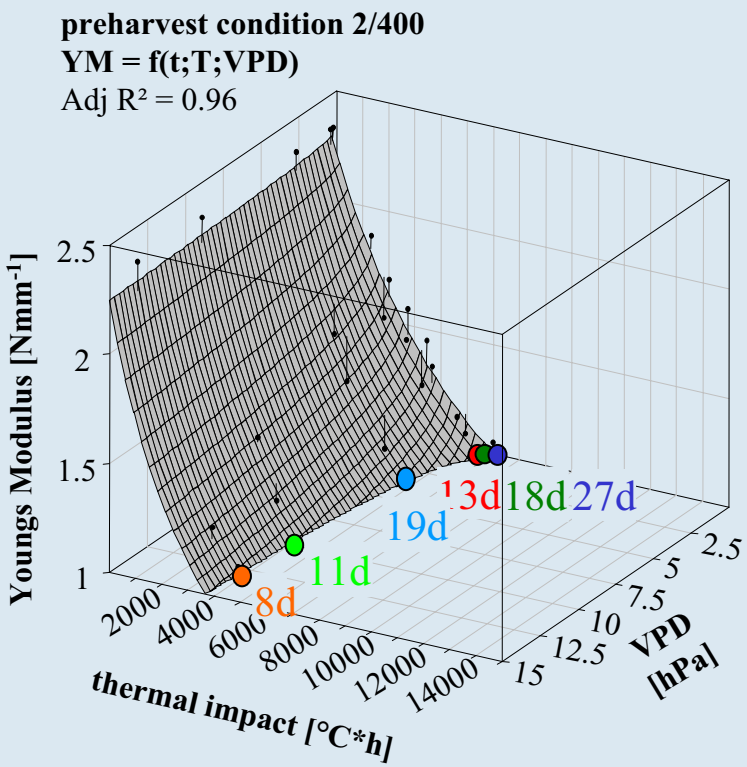
packaging	closed package (cp)			open package (op)		
storage temperature [°C]	10	15	20	10	15	20
VPD [hPa]	0.25	0.34	0.47	2.7	9.01	13.3
thermal impact [°C*h] condition 2/400	**6480**	**6480**	**6240**	**4560**	**3960**	**3840**

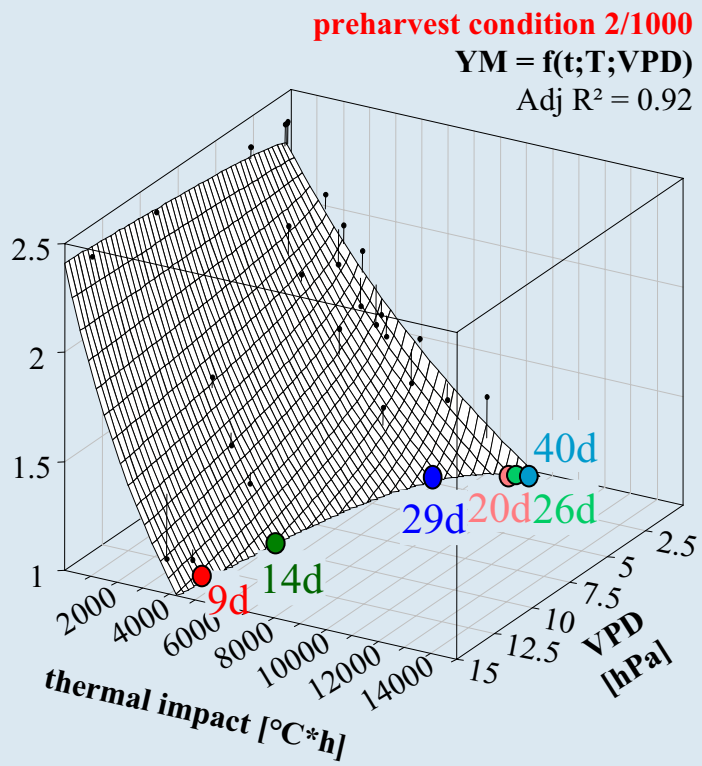


Modelling the Stiffness of Tomato

Thermal Impact + Effect of Water Regime [VPD=f(t;rH)] + Preharvest Influence

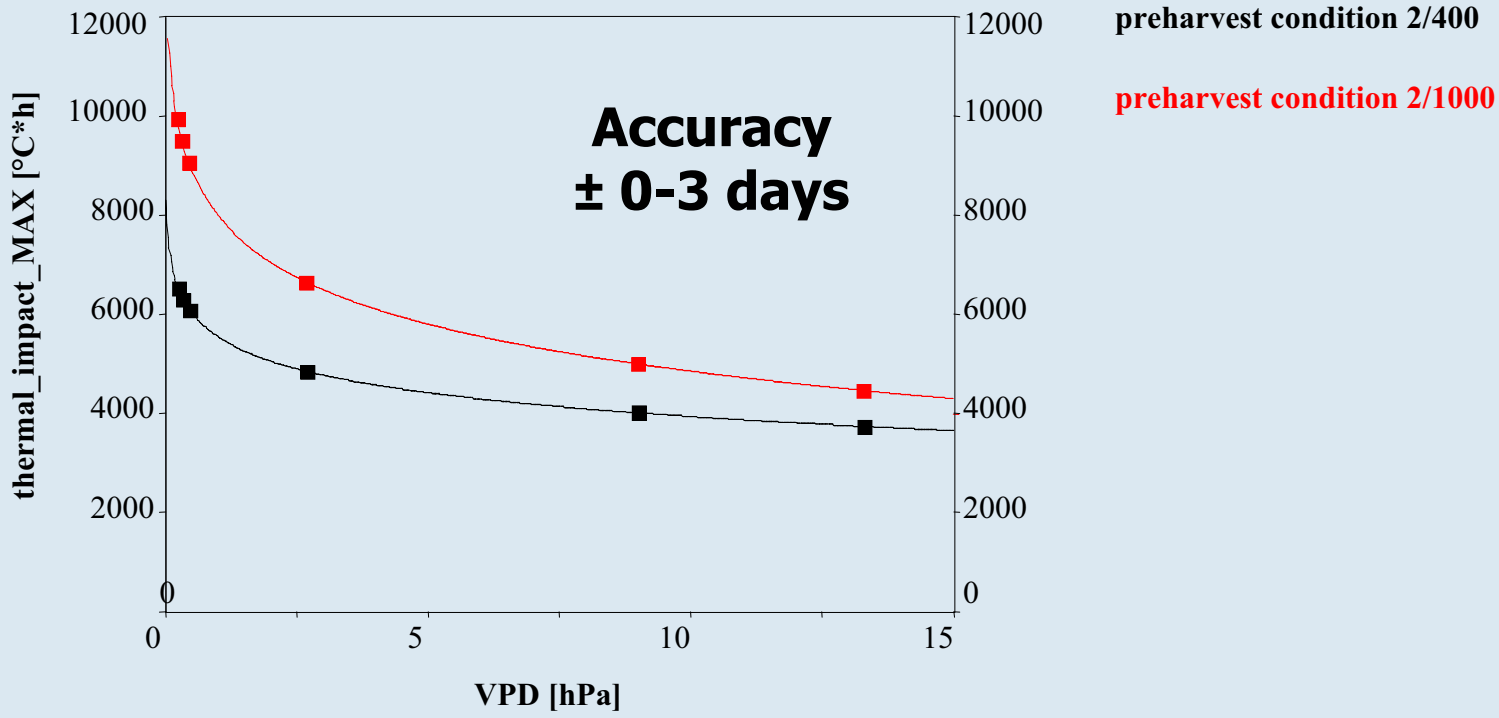
packaging	closed package (cp)			open package (op)		
storage temperature [°C]	10	15	20	10	15	20
VPD [hPa]	0.25	0.34	0.47	2.7	9.01	13.3
thermal impact [°C*h] condition 2/400	**6480**	**6480**	**6240**	**4560**	**3960**	**3840**
thermal impact [°C*h] condition 2/1000	**9600**	**9360**	**9600**	**6960**	**5040**	**4320**





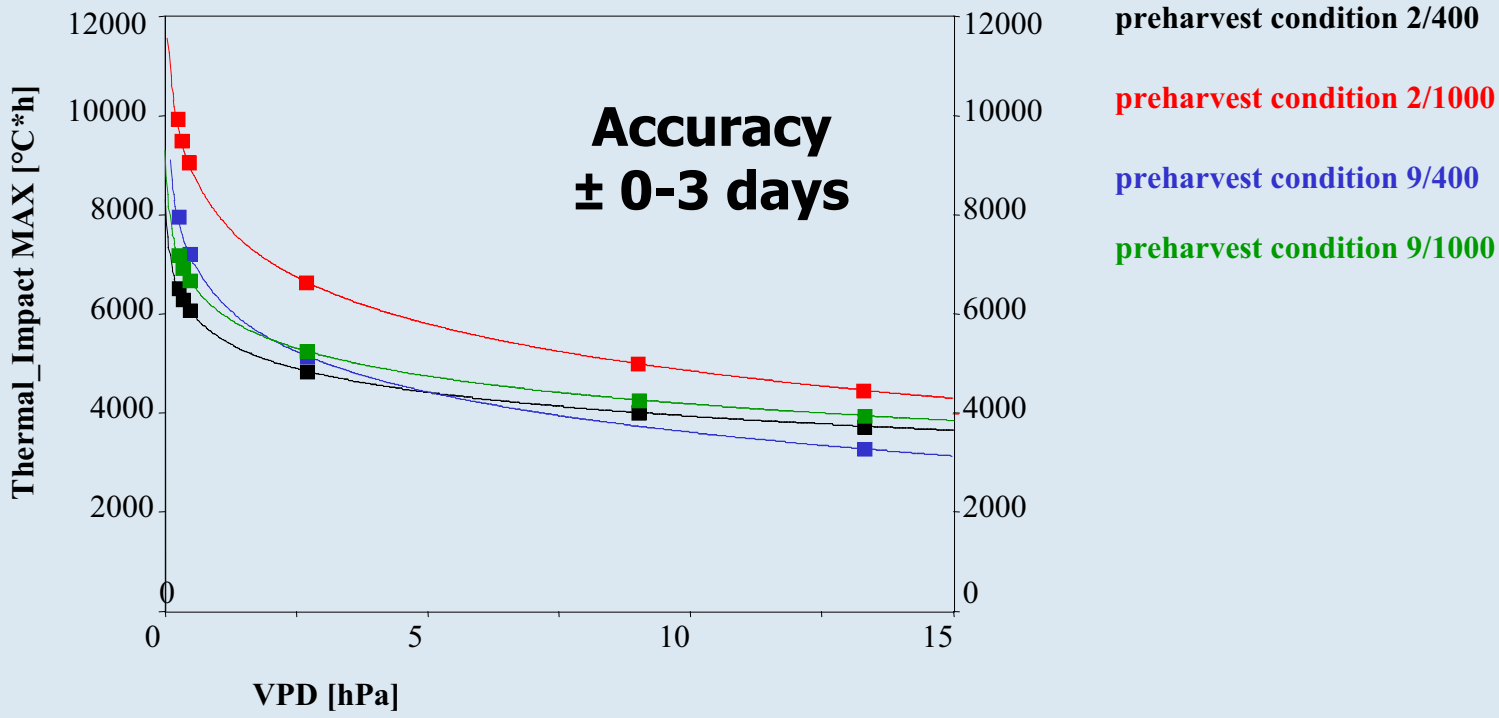
Modelling the Shelf Life of tomato

Thermal Impact + Effect of Water Regime [VPD=f(t;rH)] + Preharvest Influence

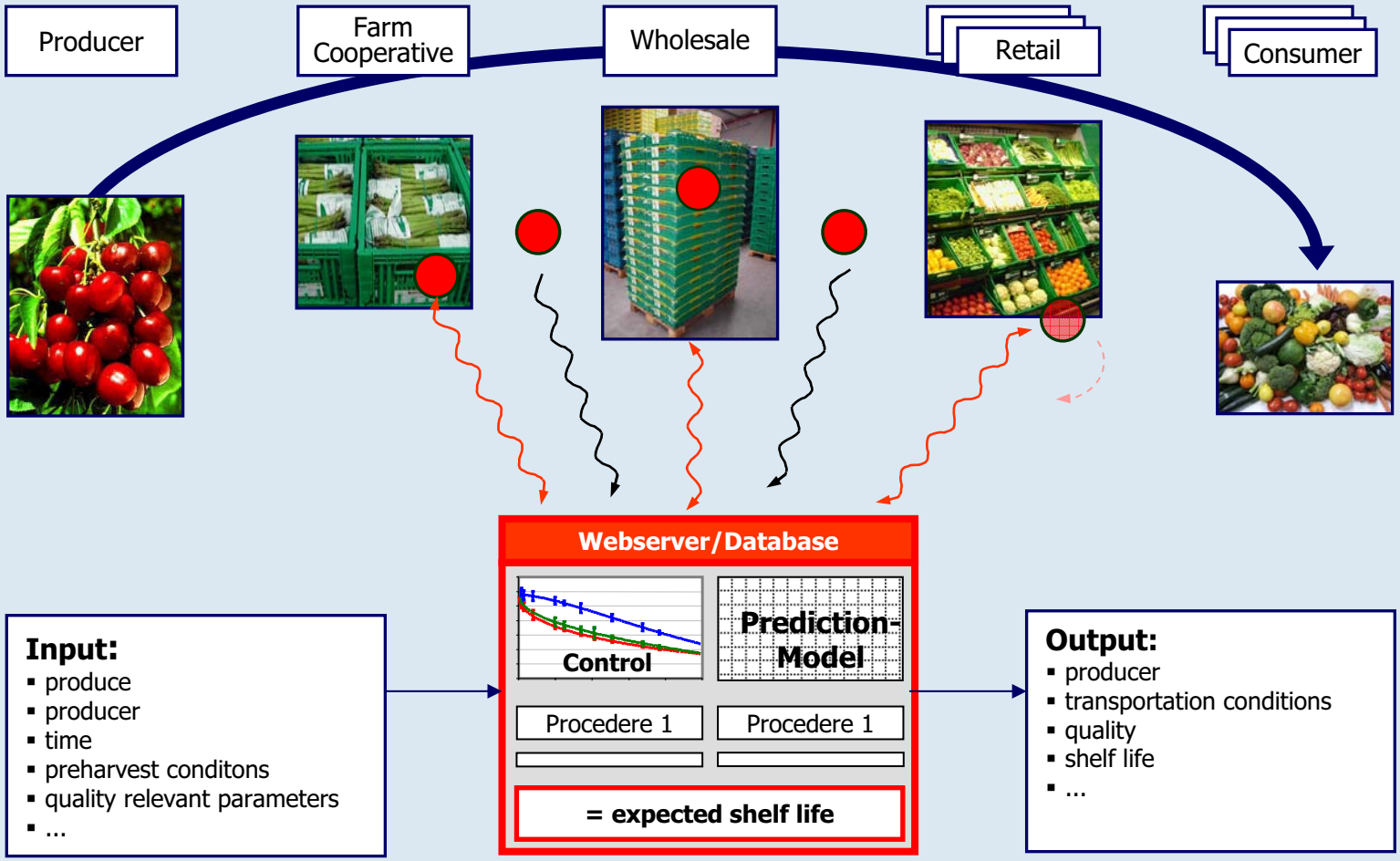


Modelling the Shelf Life of tomato

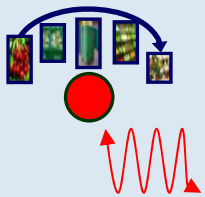
Thermal Impact + Effect of Water Regime [VPD=f(t;rH)] + preharvest Influence



Application



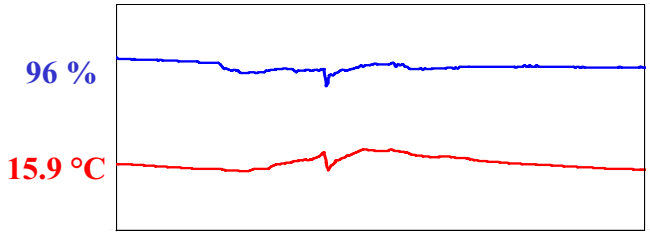
Application



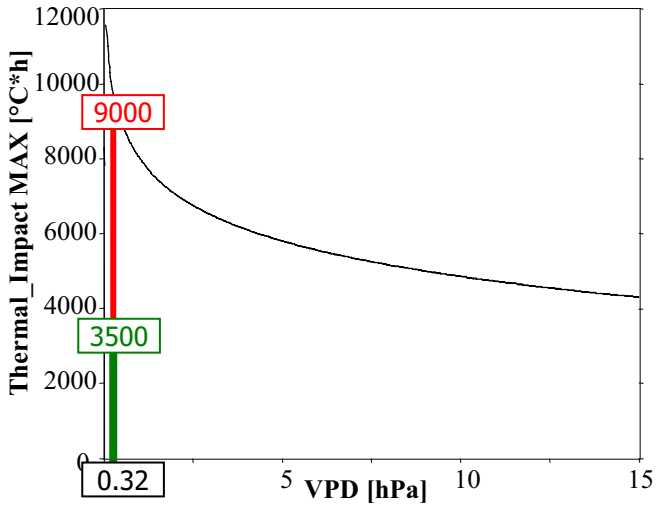
Webserver / Database

Produce	Tomato
Cultivar	Counter
Cargo [Info]	Info
...	**...**
$t_{Transport}$ [d]	10
T_{mean} [°C]	14.6
ΔT_{max24} [K]	2
rH_{mean} [%]	98
VPD [hPa]:	0.32
Therm.Imp. [°C*h]	3500
$Shelflife_{max}$ [°C*h]	9000
$Shelflife_{max}$ [d]	**25**
Remaining Shelf Life [d]	**15**
$T_{alternativ}$ [°C]	**11**
Alternative shelf life [d]	**?**

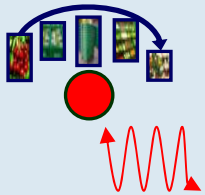
Protocoll



Prediction Model



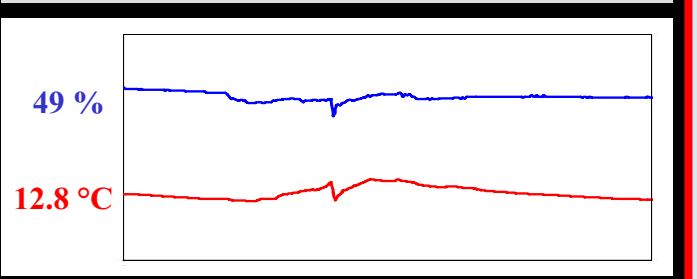
Application



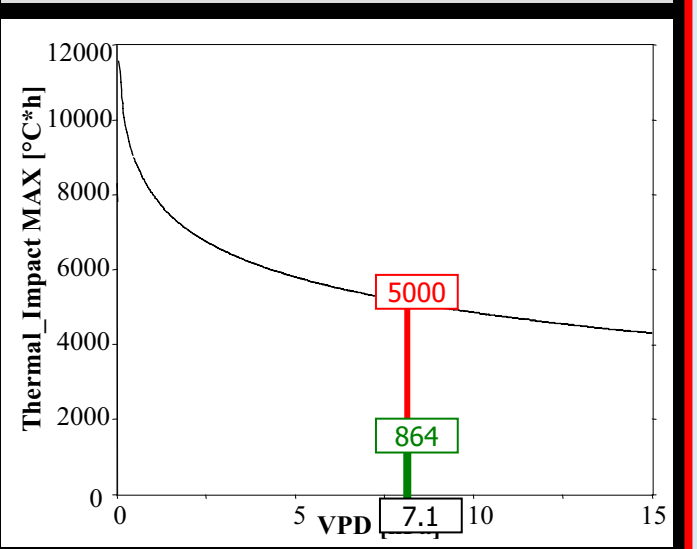
Webserver / Database

Produce	Tomato
Cultivar	Counter
Cargo [Info]	Info
...	**...**
$t_{Transport}$ [d]	3
T_{mean} [°C]	11.5
ΔT_{max24} [K]	1
rH_{mean} [%]	45
VPD [hPa]:	7.1
Therm.Imp. [°C*h]	864
$Shelflife_{max}$ [°C*h]	5000
$Shelflife_{max}$ [d]	**17**
Remaining Shelf Life [d]	**14**
$T_{alternativ}$ [°C]	**?**
Alternative Shelf Life [d]	**7**

Protocoll



Prediction Model



Summary

- Wireless datalogger as well as active RFID tags can support quality management and traceability in fresh produce supply chains
- Knowledge about produce shelf life and quality are important and needed
- Presentation of a data based system:
  - Decrease of stiffness as a function of easily measurable terms of time, temperature and water effects (VPD)

    Stiffness = f (**thermal Impact** (t,T), **VPD** (T, RH))

  - Shelf Life as a function of thermal impact and water effects

    Shelf Life = f (**thermal Impact** (t,T), **VPD** (T, RH))

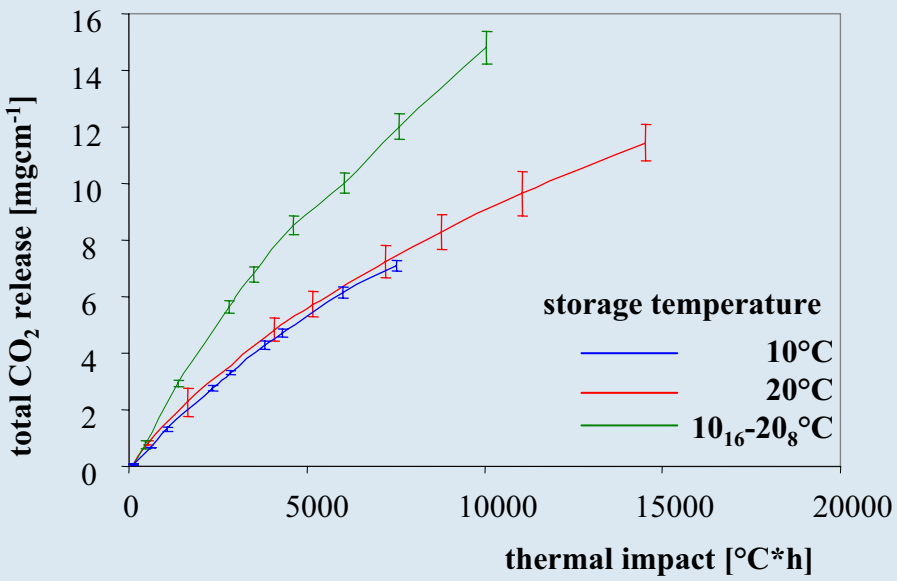
  - Development of an applicable system for monitoring the needed parameters in praxis and a practicable user interface

Future Prospects

- Further Parameters to take into account :
  - fluctuation of temperature
  - fluctuation of air humidity
  - preharvest conditions and cultivar
  - PAR in preharvest
  - .....
- Thresholds for other varieties and produces


Thank you for your attention

Modelling the shelf life of fruit depending on pre-harvest and post-harvest conditions



Temperature characteristic and expected Shelf Life of broccoli in terms of percentage as a function of thermal impact during the postharvest period

Modelling the Stiffness of Tomato

packaging	closed package (cp)			open package (op)		
storage temperature [°C]	10	15	20	10	15	20
Storage Humidity [%]	98	98	98	78	45	43
Watervapourpartial-pressuredifference [hPa]	0.25	0.34	0.47	2.7	9.01	13.3
Threshold of Marketability (Young's Modulus [Nmm^{-1}])	1					

preharvest condition	condition 2/400					
Time [d]	27	18	13	19	11	8
thermal impact [°C*h]	6480	6480	6240	4560	3960	3840

preharvest condition	condition 2/1000					
Time [d]	40	26	20	29	14	9
thermal impact [°C*h]	9600	9360	9600	6960	5040	4320

Modelling the shelf life of fruit depending on pre-harvest and post-harvest conditions

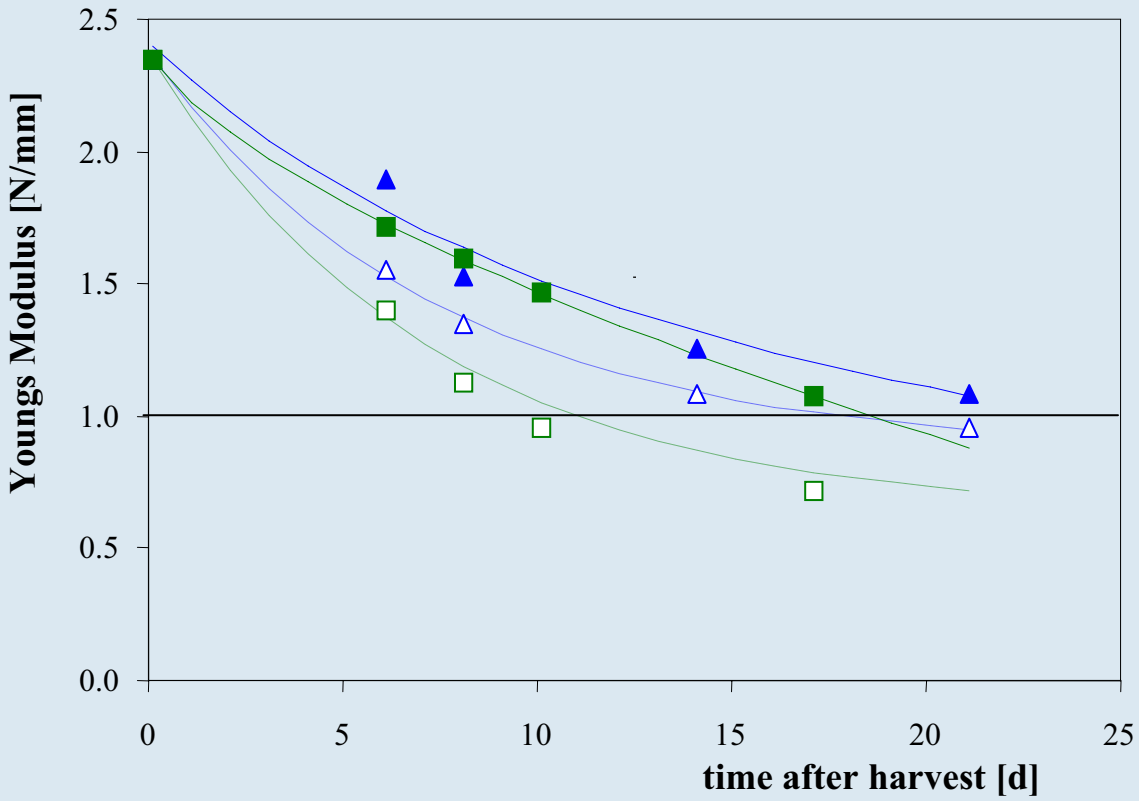
Shelflife = f **(thermal Impact** (t,T), **VPD** (T, RH) **)**

→ Shelflife = f **(thermal Impact** (t,T), **VPD** (T, RH), **δ*T**, **δ*RH** **)**

→ Shelflife = f **(thermal Impact** (t,T), **VPD** (T, RH), **δ*T**, **δ*RH**, **Param** (Produce) **)**

Modelling the Stiffness of Tomato

Thermal Impact



preharvest condition 2/400
initial stiffness ~ 2.5Nmm^{-1}
YM = f(t) Adj R^2~0.95

▲ 10°C_cp

△ 10°C_op

■ 15°C_cp

□ 15°C_op