Martin Geyer, Manfred Linke, Inka Gerbert and Oliver Schlüter, Potsdam-Bornim, and Hans-Peter Kläring, Großbeeren

Assessing the Shelf Life of Climacteric Fruits, Using the Example of the Tomato

A wireless data logger implemented with a "shelf life" prediction model is supposed to support retailers in their efforts to bring higher quality fruits and vegetables to the market and simultaneously reduce waste. The approach presented here for the development of the prediction model, with the tomato as an example, uses cultivation parameters from the preharvest period, as well as the cumulative temperatures and the vapor pressure difference (VPD) in the post harvest period.

Dipl. Ing. Manfred Linke, Inka Gerbert and Dr. Oliver Schlüter are scientists in, Dr. Martin Geyer is head of the department horticultural engineering at the Leibniz-Institut für Agrartechnik Potsdam-Bornim e.V., (ATB); e-mail: *geyer@atb-potsdam.de*
Dr. Hans-Peter Kläring ist scientist at the Leibniz-Institut für Gemüse- und Zierpflanzenbau Großbeeren und Erfurt e.V., (IGZ).

Acknowledgement

The project is funded by the German ministry of education and research (BMBF) in the frame of the collaborative project ProSenso.net2 (FKZ 0339992A).

Keywords

Shelf life, model, post harvest, preharvest conditions, tomato

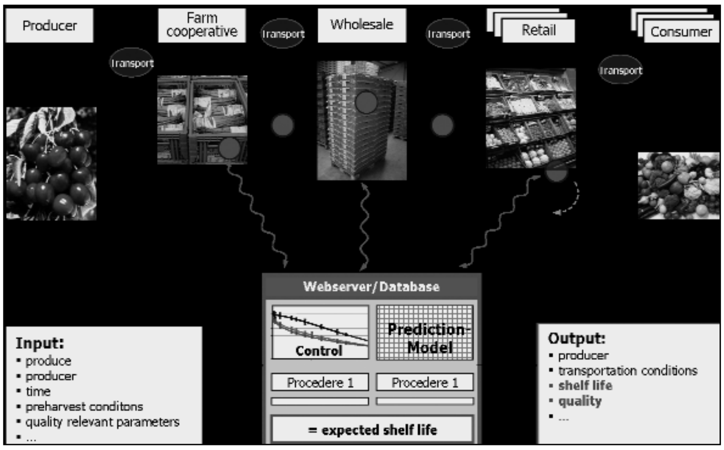

Fig 1: Implementing the wireless data logger into the postharvest chain

Modern consumers expect to have a large choice in fruit and vegetable in retail every day over the 12 months of the year. To meet this challenge the retailers need more and better information about the products themselves and their attitude in the whole supply chain, on their way from production to point of sale. The information should include, on the one hand, specifications about variety, origin, state of ripeness at harvest, and specific treatments and cultivation practices and, on the other hand, about postharvest conditions concerning packaging, temperature sum or mechanical loads.

Objective of the research project described here is to develop a wireless data logger in cooperation with a small enterprise. The data logger should measure temperature and additional parameters like relative humidity, and should send these data to the base station at every transfer point. The shelf life of every batch of produce will be calculated by an implemented program taking into account the kind of produce, the variety, the cultivation parameters, the ripeness state at harvest and the postharvest conditions temperature, relative humidity and, in the near future, air flow (*Fig. 1*).

Especially temperature and water losses, governed by produce properties and environmental conditions (packaging unit, air movement, air humidity), determine the loss of quality, i.e. the rate of spoilage of horticultural produce in the supply chain. There is a direct relationship between temperature and respiration rate. As a result, the higher the temperature the shorter is the shelf life. For instance broccoli will loose marketability within two days, yellows and starts flowering, if cooling is not available. Furthermore, relative humidity and the mass transfer coefficient affect transpiration. Especially all unpacked root vegetables, leafy vegetables, asparagus and different berry fruits are very susceptible to high water losses at low relative air humidity. The influence of temperature on the deterioration rate of fruit and vegetable and the exemplary description of this behaviour is well described in literature [i.e. 1 to 5]. The water vapour partial pressure difference (VPD) as the driving force of transpiration has been much less acknowledged in postharvest research up till now.

Materials and methods

Because of its high economical relevance, tomatoes were selected as test objects for the

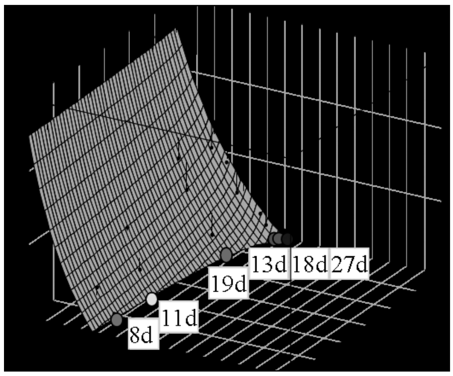

Fig. 2: Shelf life of tomatoes related to thermal impact, VPD and stiffness at constant preharvest conditions (EC2, CO_2 400 ppm)

shelf-life model. Tomato plants (*Lycopersicon esculentum Mill. cv. Counter*) were grown hydroponically on rock wool in a greenhouse at the Leibniz-Institut für Gemüse- und Zierpflanzenbau Großbeeren/Erfurt. Two preharvest cultivation parameters were varied. The electrical conductivity of the nutrient solution was set to either EC 2 and 9 dS/m, while two CO_2 concentrations in the surrounding air were adjusted to either 400 or 1000 ppm. In total 432 tomatoes were harvested in the light red state.

To measure tomato shelf life twelve single tomatoes each were placed in nearly cylindrical jars (5 l volume). To simulate different packaging conditions, one half of the jars was left open while the others were closed with a cover, which allowed gas exchange only through two holes of 0.01 m diameter each. Each of these packaging variations were stored at air temperatures of 10°C, 15°C and 20°C, respectively, over a period of three weeks. A relative humidity of approximately 98% was estimated in the closed jars. The relative humidity of the air surrounding the jars was either 78% for 10°C, 45% for 15°C and 43% for 20°C (*Table 1a*).

The limit of marketability was defined as the date the consumer would no longer buy the stored tomatoes. The first impression the consumer perceives in retail regarding to the quality of a tomato fruit is its appearance including form, size, colour and gloss. However these produce properties are not suited to objectively and non-destructively measure and define their limit of marketability. In this respect, increasing softness resp. decreasing stiffness is the suitable parameter to describe tomato quality. This parameter is easily measurable with an Instron-type universal testing machine. The postharvest softening directly relates to the temperature (loss of ingredients) and to the water loss as a result of air humidity and air flow conditions close to the surface of the produce. An expert test panel of 30 participants determined the sensory softness limit value of marketability to be equivalent to a Young`s modulus of 0.4 and 2.5 N mm^{-1} as measured with the Instron type machine (Zwicki 1120, Zwick/Roell, Ulm, Germany; with a sphere of 7 mm in diameter and a maximum force of 3 N).

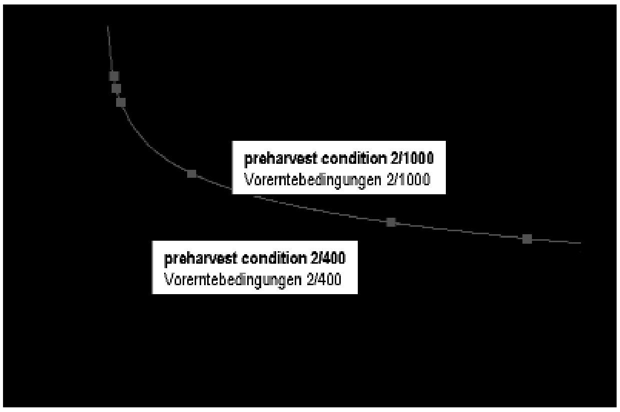

Fig. 3: Thermal impact related to VPD at constant preharvest conditions (EC2, CO_2 400 ppm)

Results and discussion

The results of the expert panel showed that tomatoes are not marketable when stiffness became less than 1 N mm^{-1}. So this value was used as the threshold for marketability for the shelf life prediction model.

The principle of developing the model is explained below taking into consideration constant preharvest conditions (400 ppm CO_2 und EC 2 dS/m), three temperatures and two relative humidity conditions at natural convection.

As expected, stiffness declined logarithmically with time. Several functions were tested for each of the three temperatures and two packaging versions. In a first step the relation between time after harvest, temperature and packaging version until the limit value of marketability was reached was calculated. On this base the decrease of stiffness was related to the cumulative temperature (thermal impact) and the water vapour partial pressure difference (VPD) between produce and surrounding air in a second step.

Taking into consideration the marketability limit of 1 Nmm^{-1}, the thermal impact necessary to reach this limit was relatively constant at any packaging version. Different shelf lives primarily result from the different temperatures (*Table 1b*). If air humidity at natural convection is included into the model, tomato shelf life increases by about one week. Correspondingly, to reach the same tomato shelf life, the fruits can be stored at 15°C and a high relative humidity or at 10°C and low relative humidity. Furthermore, the influence of temperature on stiffness is higher at low VPD than at high VPD.

The aim of the project is to develop a model to predict the residual shelf life at any step in the postharvest chain. For the calculation of the shelf life this means that only those values are relevant were the modelled area cuts the 1 Nmm^{-1} axis (*Fig. 2*). A further simplification results from the fact that, in this specific case, the thermal impact is related to VPD (hPa) (*Fig. 3*). The total shelf life and the residual shelf life can be extrapolated back from the thermal impact data. This information should be available at any step in the supply chain to the retailers, resp. to the consumers. At present the model is valid only for natural convection conditions.

Preharvest conditions affect shelf life as well. In *Figure 3* the influence of the two CO^2 concentrations (400 and 1000 ppm) during cultivation in the greenhouse is demonstrated. Shelf life in postharvest increases up to 13 days by this measure, depending on temperature and packaging conditions.

Table 1a: Treatments of respectively 12 tomatoes to develop the prediction model; b: shelf life until threshold of marketability is reached and corresponding thermal impact (EC2, CO_2 400 ppm)

a:						
Vorerntebedingungen / preharvest cond.	**Leitfähigkeit EC 2 oder 9, CO_2 400 oder 1000 ppm**					
Verpackung / packaging	**geschlossen/closed**			**offen/open**		
Lagertemperatur / temperature (°C)	10	15	20	10	15	20
Rel. Feuchte / rel humidity (%)	98	98	98	78	45	43
Wasserdampfpartialdruckdifferenz (hPa)	0,25	0,34	0,47	2,7	9,01	13,3
b:						
Haltbarkeit / shelf life (d)	26	18	13	19	11	8
Temperatursumme /thermal imp. (°C*h)	6240	6480	6240	4560	3960	3840

Literature

[1] *Artes, F., F. Garcıa, J. Marquina, A. Cano and J.P. Fernandez-Trujillo* : Physiological responses of tomato fruit to cyclic intermittent temperature regimes. Postharvest Biology and Technology 14, (1998), pp. 283–296

[2] *Dijk, C. van, C. Boeriu, T. Stolle-Smits and L.M.M. Tijskens* : The firmness of stored tomatoes (cv. Tradiro). 1. Kinetic and near infrared models to describe firmness and moisture loss. Journal of Food Engineering, 77 (2006), no. 3, pp. 575-585

[3] *Dijk, C. van, C. Boeriu, T. Stolle-Smits and L.M.M. Tijskens* : The firmness of stored tomatoes (cv. Tradiro). 2. Kinetic and Near Infrared models to describe pectin degrading enzymes and firmness loss. Journal of Food Engineering, 77 (2006), no. 3, pp. 585-593

[4] *Hertog, M.L.A.T., R. Ben-Arie, E. Roth and B.M. Nicolai* : Humidity and temperature effects on invasive and non-invasive firmness measures. Postharvest Biology and Technology 33 (2004), pp. 79-91

[5] *Schouten, R.E., T.P.M. Huijben, L.M.M. Tijskens and O. van Kooten* : Modelling quality attributes of truss tomatoes: Linking colour and firmness maturity. Postharvest Biology and Technology 45 (2007a), pp. 298-306

[6] *Schouten, R.E., T.P.M. Huijben, L.M.M. Tijskens and O. van Kooten* : Modelling the acceptance period of truss tomato batches. Postharvest Biology and Technology 45 (2007b), pp. 307-316