Postharvest Biology and Technology 123 (2017) 119–127

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

On the validation of improved quality-decay models of potted plants

Seth-Oscar Tromp*, Harmannus Harkema, Esther Hogeveen, Hajo Rijgersberg, Ernst J. Woltering

Food and Biobased Research, Wageningen University and Research Centre, P.O. Box 17, 6700 AA Wageningen, The Netherlands

ARTICLE INFO

Article history:
Received 19 April 2016
Received in revised form 20 September 2016
Accepted 22 September 2016
Available online 27 September 2016

Keywords:
Validation
Model
Quality decay
Potted plants
Transport
Storage

ABSTRACT

Storage experiments were carried out with potted plants: two *Phalaenopsis* cultivars and one *Anthurium* cultivar. The plants were stored in the dark for different storage times at different temperatures, to mimick a transport phase. Different quality aspects were scored immediately after the transport phase and after a subsequent display phase of 7 and 14 days at in-store conditions. Improved quality decay models compared to previous work were designed to quantify the effect of transport on the shelf life of potted plants.

Of each cultivar, plants were obtained from two commercial growers in the Netherlands. Only the data from the first grower were used for improving the quality-decay models. The models were subsequently validated using the data from the second grower, as well as data from the first grower from year 2013 instead of 2015. So validation took place both in origin (a different grower) and in time (a different year).

The validation showed that the behaviour of *Anthurium* 'Arion' was well predicted by the previously designed quality-decay models. For *Phalaenopsis* the performance of the quality-decay models differed per storage temperature. It was concluded that a quality-decay model first needs to be validated before it can be applied to predict the quality decay of a different production batch.

1. Introduction

The potted-plant market in Europe is steadily growing, and as a consequence increasing numbers of plants are stored and transported for prolonged periods of time. Post-production conditions such as storage and transportation can have very harmful effects on the ornamental quality of plants. On the other hand, the ornamental quality of potted plants is extremely important (Ferrante et al., 2015). To quantify the post-production plant quality loss, in our previous work quality-decay models have been developed for *Phalaenopsis* 'Tropic Snowball', *Phalaenopsis* 'Atlantis', *Anthurium* 'Chico Green', *Anthurium* 'Arion' and *Cyclamen* Super Series 'Picasso' and 'Compact' (Tromp et al., 2015). These quality-decay models describe the plant quality as a function of the storage time and storage temperature, and are composed of a so-called primary model and a secondary model. The purpose of the primary quality model is to describe the time dependency of quality. For perishable products, it is in general common to model quality change via first-order reaction kinetics or a sigmoid (logistic) curve (Tijskens and Polderdijk, 1996). Loss of perceived quality over time is the result of a cascade of biochemical reactions. Such cascades, which are mostly only poorly understood, can often be approximated by a logistic curve (Tijskens et al., 1996). The purpose of the secondary quality model is to describe the temperature dependency of quality. A common secondary model for describing the temperature dependency is an Arrhenius equation (Tijskens and Polderdijk, 1996). For example, Rijgersberg and Top (2006) have applied Arrhenius for modelling the temperature dependency of the quality of fresh-cut endive, where Tromp et al. (2012) have shown that the temperature dependency of the quality of cut roses can be modelled according to Arrhenius.

Numerous quality-decay models have been developed for specific food products. For example, McDonald and Sun (1999) have given an overview of models for predicting the quality of meat, while Hertog et al. (1999) have modelled the quality of strawberries packed under modified atmospheres. Lukasse and Polderdijk (2003) have presented a methodology for modelling quality evolution of perishables and have demonstrated this methodology for mushrooms.

In this paper, the recently developed quality-decay models of potted plants were improved using a larger data set. For this a new storage experiment was conducted. When developing the earlier quality-decay models, the model describing the effects of time and temperature on quality decay did not take into account important

* Corresponding author.
E-mail address: seth.tromp@wur.nl (S.-O. Tromp).

http://dx.doi.org/10.1016/j.postharvbio.2016.09.008
0925-5214/

storage differences between the transport phase and the in-store phase. Transport took place in dark and plants were not watered, whereas the display phase was in a 12 h dark/12 h light condition and plants were watered regularly. The model was improved by incorporating this difference.

Moreover, the improved models were validated in this paper. External validation of the improved quality-decay models took place by comparing a plot of simulated versus actual outcomes over a wide range of experimental treatments (Cox, 1996). The models were validated twice, both in time (with a production batch from the same grower, but from year 2013 instead of 2015) and in origin (with a production batch from the same season in 2015, but from a different grower).

This paper is organized as follows. In Section 2, the setup of the storage experiment is described, including the way of quality scoring. In addition, both the improved modelling approach and the validation approach are explained. In Section 3, both the experimental results, the modelling results and the validation results are presented. In Section 4, these results are discussed by comparing model predictions with experimental data.

2. Material and methods

2.1. Experiment

2.1.1. Plant material and experimental setup

The storage experiment was carried out with *Anthurium* 'Arion', *Phalaenopsis* 'Atlantis' and *Phalaenopsis* 'Tropic Snowball'. The potted plants for the experiment were obtained from the same commercial growers in the Netherlands as in our earlier experiment (Tromp et al., 2015). Moreover, for each cultivar a batch of potted plants was obtained from a second commercial grower in the Netherlands. The potted plants were transported within two hours from the grower to the laboratory. *Phalaenopsis* (April–May 2015) and *Anthurium* (March 2015) plants were delivered in 12-cm pots. The plant height of *Phalaenopsis* was approximately 60 cm, and the plant height of *Anthurium* 'Arion' was 50 cm. In the commercial harvesting stage, *Phalaenopsis* plants contained three flowering stems, each with 1–3 open flowers and a number of closed buds. *Anthurium* plants had on average four coloured spathes. Plants were delivered in plastic sleeves. Before the storage experiment, plants were well watered.

In order to mimic a transport phase, the sleeved plants were held in darkness in plastic trays without the addition of further water, for different periods of time (*Phalaenopsis* for 4, 7, 11, 14, 19 and 22 days at 10 °C, for 5, 11, 15, 20, 27 and 34 days at 15 °C, for 5, 11, 15, 20, 27 and 34 days at 20 °C and for 4, 7, 11, 14, 19, 22 and 26 days at 25 °C; *Anthurium* for 3, 7, 10, 14 and 17 days at 5 °C, for 10, 16, 21, 28 and 37 days at 10 °C, for 7, 14, 21, 28, 37 and 42 days at 15 °C and for 3, 10, 16, 21, 28 and 37 days at 20 °C). Storage times and temperatures were chosen such that the effect of transport on plant quality could be studied at both optimal and suboptimal temperatures. *Phalaenopsis* and *Anthurium* have a reputation as very sensitive to low temperatures. Recommended transport temperatures are 15–18 °C for *Phalaenopsis* and 10–15 °C for *Anthurium*. *Phalaenopsis* and *Anthurium* were stored at the recommended temperatures and at higher and lower temperatures. The vapour pressure deficit (VPD) is an important driving force for evaporation. To obtain a comparable VPD (140–160 Pa), the relative humidity (RH) was different for each storage temperature: 83% at 5 °C, 88% at 10 °C, 91% at 15 °C, 94% at 20 °C and 95% at 25 °C.

Immediately after the transport phase, sleeves were removed, plants were watered and held for 14 days under conditions mimicking a display phase in e.g. a flower shop or supermarket. The climate conditions during the display phase were 20 °C and 60 ± 5% RH, 12 μmol m^{-2} s^{-1} light from fluorescent tubes for 12 h per day. During the display phase the plants were watered when needed (once or twice a week), according to the protocol of the Dutch Flower Auctions Association (Association of Dutch Flower Auctions (VBN), 2007).

For each combination of storage time and storage temperature, 6 *Phalaenopsis* or 8 *Anthurium* plants from one grower were tested. As controls, 18 *Phalaenopsis* or 24 *Anthurium* plants were placed immediately under the conditions mimicking the display phase, after bring to the lab (i.e. without dark storage mimicking a transport phase).

2.1.2. Quality scoring

The quality of the potted plants was scored both immediately after the transport phase (so just before the display period), and after a subsequent display period of both 7 and 14 days. *Phalaenopsis* plants were scored based on the desiccation and abscission of buds and flowers, leaf yellowing and the occurrence of darkened areas on the leaves, later developing into water soaked areas as symptoms of chilling injury. *Anthurium* plants were scored based on the quality of the leaves (yellowing, dark areas and dry leaf edges), the spathe (yellowing, dehydration, dullness) and the spadix (browning).

A scale from 1 to 9 was applied (Table 1), according to which plant physiological experts scored the quality of the potted plants on indicators such as number of dried flowers, number of abscised flowers, fungal infection of flowers and foliage, leaf yellowing and chilling injury (dark spots on the foliage, developing in rotten leaves). For both *Phalaenopsis* and *Anthurium*, a Supplementary file is added where for the quality scores in Table 1 a photo is associated. The quality assessment was conducted by two physiological scientists, sometimes together to stimulate convergence of the assessments. The obtained measurement data are provided in a third Supplementary file.

2.2. Model design

The models is composed of a so-called primary model (a logistic curve) and a secondary model (Arrhenius' law). The combination of a primary and secondary model is applied in different scientific

Table 1
Rating scale for scoring the quality of potted plants.

Quality score	Description
9	very good; no defects on foliage or flowers/spathe, spadix
8	good; minor defects on foliage or flowers/spathe, spadix
7	fairly ok; minor defects on foliage and flowers/spathe, spadix
6	sufficient; some defects on foliage and/or flowers/spathe, spadix
5	almost sufficient; defects on foliage and/or flowers, some dried—and/or abscised buds or—flowers
4	insufficient; serious defects on foliage and/or flowers, dried buds, abscised flowers
3	diminutive; serious foliage yellowing, rotten foliage, serious bud—and/or flower abscission, rotten flowers
2	bad; total collapse of flowers or foliage
1	very bad; total collapse of flowers and foliage