Predicting Rose Vase Life in a Supply Chain

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Abstract

With increasing market globalization quality management of cut flowers is a necessity. An important attribute of quality of cut flowers is their vase life at the final consumer. However, techniques to measure the potential vase life at points of sale in the chain are not available at this moment. Vase life is largely affected by the conditions (temperature, duration and handling) in the supply chain. Therefore, simulation models that can predict vase life based on temperature and time, as measured by data loggers, could be very valuable. Moreover, such simulation models could be used for scenario studies to investigate quality critical control points. A previously published simulation model, based on data from literature, was validated for cut rose flowers using data of a vase life experiment with flowers stored at 1, 5, 8 and 12°C for periods varying between 2 and 39 days. The experimental setup was designed to exclude the occurrence of *Botrytis* and water uptake problems due to bacteria as much as possible. The experimentally obtained vase life data confirmed that the relationship between temperature and loss of vase life during storage is not linear, but could well be described by a sigmoidal curve. The predicted vase life applying the simulation model correlated very well to the measured vase life. However, the vase life after long storage was underestimated; this could be improved by adapting the maximum rate of vase life-loss for the specific cultivar using the vase life of fresh cut flowers without storage.

INTRODUCTION

The cut flower market is a globalized market, with flowers grown in one part of the world being sold in another part of the world. As a result, cut flowers are transported for several days or even weeks over various distances. The quality of the flowers at the final consumer will be affected by the transport conditions, of which temperature is one of the most critical ones (Goszczynska and Rudnicki, 1988; Nell and Reid, 2000; Kader, 2002). However, temperature in commercial flower chains is still poorly managed, partly because its effect is not always well understood. Before investing in a temperature controlled (cold) supply chain it is worthwhile to know the added value of the investment. Simulation modelling may be used to identify critical points for quality management in a particular supply chain (van Meeteren, 2007, 2009), and to get an estimation of the added value of investments. Techniques to measure the potential vase life of cut flowers at points of sale in the chain are not available at this moment. Therefore, buyers can only take past experiences with specific supply chains into account to judge the flowers. Simulation models that can predict vase life based on temperature and time, as measured by data loggers, could also be very valuable to inform buyers about the expected vase life. A previous simulation model (van Meeteren, 2007, 2009) was based on limited available data from literature and was not validated. In this paper we describe a validation experiment with cut rose flowers. Vase life of the flowers was determined after storage at 1, 5, 8 and 12°C for periods varying between 2 and 39 days.

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MATERIALS AND METHODS

Plant Material and Experimental Setup

Cut rose flowers 'Red Naomi' were obtained from a grower in The Netherlands. The combination of cultivar and grower were selected on the basis of a preliminary experiment. Batches of roses from several growers-cultivar combinations were compared on *Botrytis* incidence. The grower and cultivar combination providing roses with the lowest *Botrytis* incidence were selected to deliver the roses for the main experiment. The cut flowers of the main experiment arrived on the day of harvest, which took place in the morning. They were harvested at the commercial development stage and dry stored until arrival at the lab facilities. After arrival, the flowers were placed in clean buckets with clean tap water at 20°C for 2 h and re-cut to 55 cm. To get as uniform bunches as possible, flowers that were too mature, too immature, had very thin or very thick stems were removed. Flowers were wrapped in plastic conical sleeves in groups of 10 and placed in cardboard boxes. Approximately 6 bunches were placed in each box. The boxes were placed in four temperature and humidity controlled rooms at 1, 5, 8, and 12°C. 40 flowers will be cut to a length of 45 cm (including the flower). Ten additional flowers were placed in a vase solution with water + 50 ppm HQS to determine the vase life without storage. At regular times, a bunch was taken out of a box from storage for vase life determination. Each time that a bunch was taken from a box, it was replaced by a dummy bunch from the same storage condition. The storage time that a bunch was taken from storage varied with storage temperature (Table 1).

Vase Life Determination

As soon as the flowers were taken form storage, the sleeves were removed. Lower leaves are removed and flowers were re-cut to 50 cm. The bunches were placed in sterile buckets with 5°C water and left for 2 h to rehydrate. Upon rehydration, flowers were once again recut to a length of 45 cm including the flower and transferred to a 20°C vase life room with 15 µmol m^{-2} s^{-1} PAR supplied in a 12-h photoperiod. The flowers were placed in water + 50 ppm HQS; one flower/vase. The flowers were observed for end of vase life symptoms every 2-3 days. Each flower was observed for signs of *Botrytis*, petal wilting, change of colour and bent neck. When vase life was deemed over, the flower was removed and discarded.

Simulation

Simulation was carried out on the basis of the vase-life model presented in van Meeteren (2007). This model assumes that flower senescence is a developmental process from stage zero (commercial harvesting stage) to unity (senescent stage ≈ end of vase life) with a rate that is affected by temperature but not by the developmental stage of the flower. End of vase life was calculated on the basis of estimated senescence stage and the potential vase life of the specific flower at harvest, ergo vase life without storage. For this validation experiment, only development (senescence) was taken into account, not *Botrytis*. Based on previous results (van Meeteren, 2007), Equation (1) was used to describe the effect of temperature on senescence-rate:

$$k_s = \frac{k_{\max}}{1 + 10^{(T_{half} - T_s).slope}} \qquad (1)$$

in which k_s [day^{-1}] = rate of senescence at temperature T_s [K], k_{max} [day^{-1}] = maximum rate of senescence, T_{half} [K] = temperature at which the senescence rate is half of k_{max}, and slope [K^{-1}] describes the steepness of the curve. Parameterization was done using data of the rose 'First Red' from Çelikel and Reid (2005), as described before (van Meeteren, 2007). Çelikel and Reid made no discrimination between senescence or water deficit related reasons (like bent neck) for end of vase life. Similarly, we also did not made discrimination between reasons for end of vase life.

Statistical Tests

Statistical tests were performed using GraphPad Prism version 5.04 for Windows, GraphPad Software, San Diego California USA, www.graphpad.com.

RESULTS AND DISCUSSION

Figure 1. shows the measured vase lives of the flowers from the fresh harvested roses and from the various storage temperature-time combinations. The results show that within each time-temperature treatment, treatments kept in storage longer had significantly lower vase life and non-stored controls had the highest vase life of about 14 days. As mentioned in Material and Methods, for the simulation runs, the parameters calculated for the rose 'First Red' were used, except for the potential vase life at harvest; for that we used 14 days (Çelikel and Reid found about 10 days for 'First Red'). The simulation showed a rather good linear relation between measured and simulated vase life of all storage treatments (Fig. 2). The percentage variance accounted for (R^2) of the linear relation is 88% with a standard deviation of the residuals of 1.6 day and normally distributed residuals (D'Agostino and Pearson omnibus normality test). However, the slope is between 1.1 and 1.4 (95% confidence interval), indicating that for short remaining vase life's (long storage, high temperatures) the simulation underestimates vase life, while at long vase life's (short storage, low temperature) the simulation overestimates vase life. This might be related to the faster senescence rate of 'First Red' compared with 'Red Naomi'. Calibrating the model on vase life data for different flowers (sunflower, gerbera, 'jonquil' narcissus, narcissus 'Paper White', rose 'First Red', *Gypsohila*, daffodil, iris, and carnation) (van Meeteren, 2007) showed that the difference in the temperature-development rate relationship for the different genotypes was mainly due to differences in the maximum senescence rate (k_{max}). Therefore, we assumed that the main difference in vase life behaviour between roses 'First Red' and 'Red Naomi' was determined by differences in k_{max}. k_{max} for 'Red Naomi' was re-calculated using Equation (2) under the assumption that T_{half} and the slope are identical between the two cultivars. The potential vase life (VL_{pot}) resembles the vase life of fresh harvested flowers.

$$k_{\max} = \frac{1 + 10^{(T_{half} - 293.15).slope}}{VL_{pot}} \qquad (2)$$

Figure 3 shows the linear relation between measured and simulated vase life using this adapted k_{max}. This adaptation did not result in an improvement of the regression coefficient (R^2=86.2%) or the standard deviation of the residuals (1.5 day), but the slope decreased to 1.08 (95% confidence interval from 0.90 to 1.25) indicating that there is no longer an over- or underestimation depending on length of storage and/or storage temperature. Over the whole range of storage conditions the difference between measured and simulated vase life is about 1 day. Although the flowers were strictly selected for uniformity and a bactericidal compound was added to the vase water, the standard variation of measured vase life in the vase life experiments was large (0.6-3.4 days), as often seen in vase life experiments. Secondly, judging end of vase life is rather subjective and this will results in different parameter estimates for both experiments (from Çelikel and Reid and ours). Thirdly, the parameters used were obtained with another rose cultivar.

We also analysed if a temperature sum approach for the relation between time-temperature-senescence could be used. However, this justified the conclusion from van Meeteren (2007) that the relationship between temperature and senescence rate is not linear, especially for the lowest storage temperature which invalidates the concept due to the commercial importance of low temperature transport.

Vase life of stored cut rose flowers can be rather well predicted by simulating the remaining vase life based on temperature and time, as measured by data loggers. The results indicate that a measurement of vase life of fresh harvested roses might be sufficient to adapt the parameters used in the simulation if a new cultivar is used. A next step in validation will be storage at fluctuating temperatures, as well as using data from commercial flower transport chains.

ACKNOWLEDGEMENTS

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Tables

Table 1. Overview of the storage times at different temperatures after which flowers were taken out of storage and used for vase life determination.

Storage temperature (°C)	Storage times when samples were taken (days)
1	4, 9, 14, 19, 23, 33, 39
5	2, 4, 7, 12, 16, 19, 26, 33
8	2, 4, 6, 9, 12, 15, 19
12	2, 4, 6, 9, 12, 15

Figures

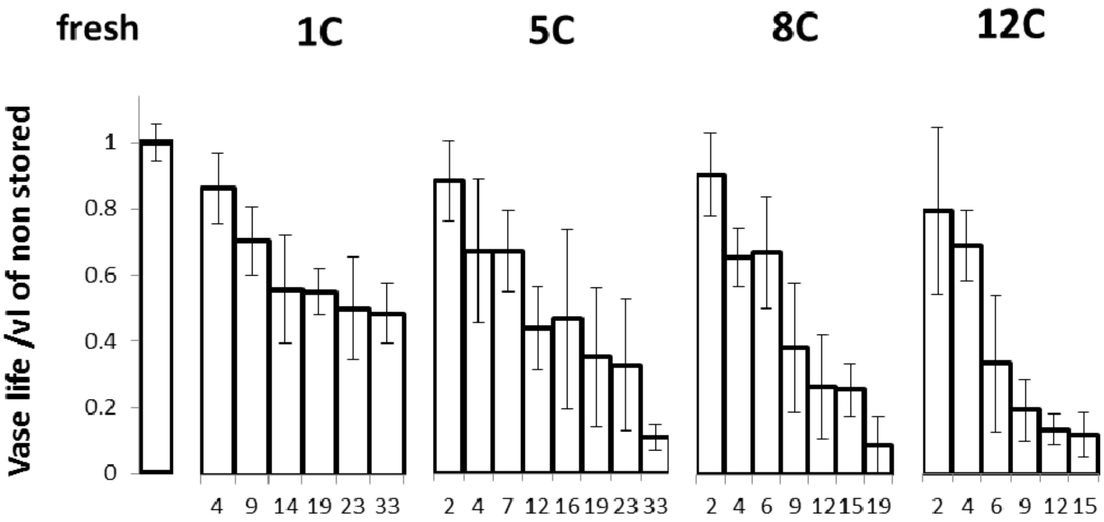

Fig. 1. Vase life of cut rose flowers ‘Red Naomi’ immediately after harvest (fresh) or after storage at 1, 5, 8 or 12°C for various periods. Vase life expressed as ratio of the average vase life of non-stored flowers. Mean values of 10 flowers/treatment; vertical bars indicate standard deviations.

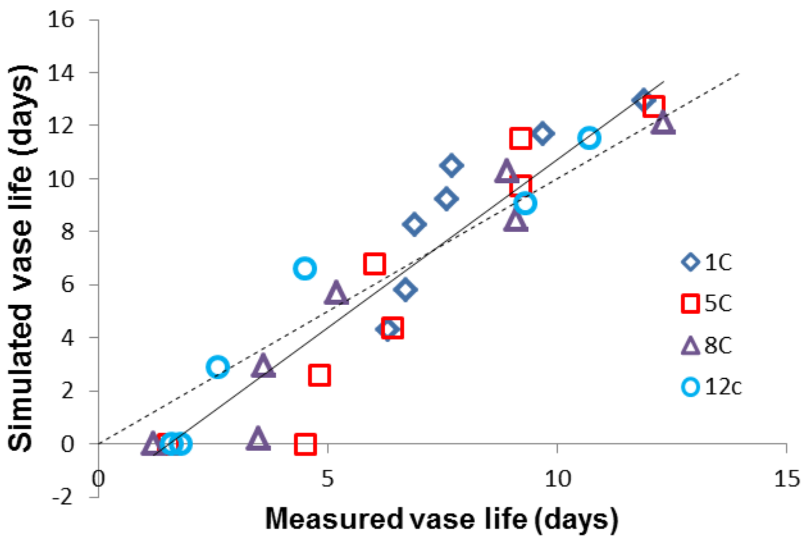

Fig. 2. Relation between measured and simulated vase life. The solid line represents the linear relation curve between measured and simulated vase life, y=1.27x-1.93. The dash line is the 1:1 linear curve.

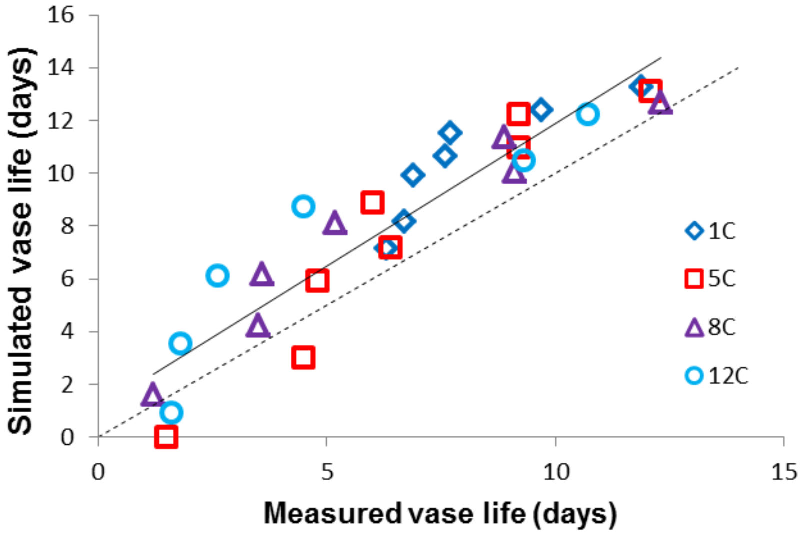

Fig. 3. Relation between measured and simulated vase life, with adapted k_{max} based on measured vase life of fresh harvested flowers. The solid line represents the linear relation curve between measured and simulated vase life, y = 1.08x + 1.12. The dash line is the 1:1 linear curve.