Effects of Low O_2 on Cut Rose Flowers at Suboptimal Temperature

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Abstract

There is no commercial application of modified atmosphere storage or packaging for cut flowers. The reason for that would be that the most decisive factor for keeping quality is a low temperature during storage and transport. In practice, however, this low temperature is not always realised. However it is worthwhile knowing potential quality benefits that may arise from the use of modified O_2 and/or CO_2 concentrations at sub-optimal temperatures. Experiments have been conducted on cut rose flowers 'First Red' to study the effect on postharvest physiology of different O_2 partial pressures (0.5-21 kPa) during 5 days at 12 °C. During this period of transport simulation at different O_2 partial pressures, respiration rate and ethylene production of the flowers was measured. During subsequent flower opening during vase life, diameter and longevity of the flowers were recorded. Fresh weight and area of single petals were measured daily. Growth during vase life of the inner and outer petal surfaces was estimated. Oxygen uptake rate and ethylene production were logarithmically related to O_2 partial pressure. To lower oxygen uptake rate to less than 50% of that in air, a partial pressure of O_2 should be <2 kPa. However, in the O_2 range <2 kPa the R(espiratory) Q(uotient) indicated anaerobic respiration. Vase life was not significantly affected by O_2 concentrations during a 5 day storage period. Low O_2 partial pressures during storage resulted in poor flower opening afterwards. Petal growth was not inhibited by low O_2-storage, but outer petals showed a greater increase in surface area and fresh weight after storage at 1 kPa O_2 than at higher O_2 partial pressures. Poor flower opening was the result of an increase in cell size at the upper region of the outer petal layer, which hampered outward reflex of the petals.

INTRODUCTION

The growing worldwide importance of cut flower production in regions far from major markets has created the need to improve conveyance and package systems for flower products, so as to assure satisfactory qualitative standards. According to the review of Goszczynska and Rudnicki (1988) Controlled Atmosphere (CA) storage and Modified Atmosphere Packaging (MAP) are promising techniques for storage of cut flowers. Meir et al. (1995) reported improved keeping quality of mini-gladiolus spikes by MAP. However, there is no commercial application of CA or MAP for cut flowers. In contrast to vegetable and fruit produce, data available in the literature on the use of CA for cut flowers are scarce. Probably the reason for that is that the most decisive factor to maintain appropriate quality for the consumer is a low temperature (just above freezing point) during storage and transport (Reid, 2001a).

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In practice this low temperature is not always realised. Therefore it is of interest to determine the response of flowers to modified O_2 and/or CO_2 concentrations at sub-optimal temperatures.

A preliminary experiment with 'First Red' cut rose, in which the CO_2 partial pressure was increased to 5 kPa and/or the O_2 partial pressure was lowered to 2 kPa during 5-d storage at 12 °C, indicated a small positive effect of low oxygen partial pressure on subsequent vase life. No clear effect of increased CO_2 was found. Further increase of CO_2 partial pressure to 10 kPa did not positively affect vase life. Therefore the research was focussed on effects of low oxygen partial pressures during storage at 12 °C on some post-harvest physiological processes of cut rose flowers.

MATERIAL AND METHODS

Plant Material

'First Red' cut rose flowers were obtained from a commercial grower. They were harvested in the morning and transported to the laboratory as soon as possible. After arrival stems were re-cut to a length of 45 cm. Flowers were then grouped in uniform bunches (5 or 8 flowers for different experiments), wrapped in a sheet of porous paper and placed in storage containers.

Storage

Flowers were stored for 5 days at 12 °C in stainless steel flow-through containers (about 200 L). In the flow-through system, pure N_2 and O_2 were mixed using mass flow controllers. A range of gas conditions was selected (0.5, 1, 2, 6 and 21 kPa O_2) and the flow rate used was 500 $ml \cdot min^{-1}$. The gas entering each container was directed through a water flask, resulting in a relative humidity close to saturation (97-99%). There were two containers used for every O_2-treatment, 5-8 flowers/container; flowers from one container were treated as one experimental unit. After storage, cut stem ends were trimmed by 5 cm and flowers were placed in tap water in a standard vase life evaluation room.

Respiration Rate and Ethylene Production

Respiration rate and ethylene production were measured after 2 days of storage at the different gas conditions. For that purpose, roses (4 for each storage condition) were placed in flow-through glass cuvettes (1.8 L). For measuring gas exchange, the gas stream through the cuvettes was temporary stopped. For respiration measurements headspace O_2, CO_2, and N_2 concentrations were measured with a Chrompack CP 2002 gas chromatograph (GC) equipped with an automatic sample system. Gas was sampled directly from the cuvettes. The exact time of measurement was logged. The time period between first and second measurement was approximately 4 hours. To convert gas levels from percentages to partial pressures, total pressure in the cuvettes was measured (with a Druck PDI 265).

Ethylene production of flowers was measured also. The air stream through the cuvettes was stopped and headspace ethylene concentrations were analysed by with-drawing 2.5 ml samples from the cuvettes, and injecting them into a gas chromatograph (Chrompack model 437 A). Because of the low ethylene production by the flowers, a second sample was taken after 24 hours. Gas exchange rates were calculated by expressing the mol differences between the two measurements per unit time (s) and per unit weight (kg fresh weight at the start of the experiment).

Flower Diameter, Petal Area and Cell Sizes

Flower diameter was determined as the average of the largest and smallest diameter of a flower. Petal areas were estimated by image analysis of digital pictures of isolated petals.

For estimating cell sizes of the inner petal surface an imprint of a basal and an upper region of a petal was made (primary replica) using non-phytotoxic silicon-based

curing material and activator (Xantopren L blue, Heraeus Kulzer, Dormagen, Germany). With a polystyrene solution in toluol, a second (transparent) replica was made which was used to count the number of cells (microscopically 40x) of a known area (about 38000 μm^2). Average cell size was calculated as the total area/number of cells. This method could not be used for the outer petal surface (quality of imprints was poor). For estimating cell sizes of the outer surface a part of the petal epidermis was stripped off. This epidermal piece was investigated in the same way as the polystyrene replica of the inner petal surface. As it was more difficult to discern cells from the epidermal piece, cell numbers were less precise, leading to more scattered data for the outer petal surface.

RESULTS

Lowering O_2 partial pressure decreased respiration rate measured as O_2 uptake rate (Fig. 1A). The response was logarithmic; to reduce O_2 uptake rate to about 50% of that in normal air, O_2 partial pressure had to be less than about 2 kPa. Oxygen partial pressures below 1-2 kPa, however, caused a large increase in CO_2-production rates of the flowers (Fig. 1B), resulting in a respiratory quotient (RQ) far above 1 (Fig. 1C).

Also ethylene production rate of rose flowers showed a logarithmic response to O_2 partial pressure (Fig. 2).

Longevity visually judged on flower appearance during vase life was only marginally improved (0.6-0.7 d) by O_2 partial pressures of 1-6 kPa during preceding storage in comparison with storage in air (data not shown). Time to peak fresh weight was not significantly affected by oxygen partial pressure.

There was a negative effect of low oxygen-storage on flower opening during subsequent vase life (Fig. 3, Table 1). To see whether flower opening was inhibited after low oxygen-storage by an inhibition of petal enlargement, in two experiments petals were taken from flowers after 3 and 6 days of vase life subsequent to a 5 days-storage at 21 kPa or 1 kPa O_2. Outer and inner petals were sampled separately. There were no significant differences in petal fresh weight between storage treatments (data not shown). In another experiment, changes in petal fresh weight and surface area were investigated from isolated petals placed in water after they were taken from flowers stored at several O_2 partial pressures and non-stored flowers. Petal growth was not inhibited by the low O_2-storage in comparison to storage in 21 kPa O_2, but instead the outer-petals showed a greater increase in fresh weight (not shown) and surface area (Fig. 4) after treatments at 0.5-6 kPa O_2. The low O_2 seems to have partly nullified the negative effect of storage. Changes in petal fresh weight and surface area of the inner-petals were not affected by preceding O_2-storage partial pressures (data not shown).

The inhibited flower opening of low O_2-stored flowers was mainly due to the outward reflex of the upper part of the petals being hampered (Fig. 5). To investigate if this was caused by the effects of storage conditions on differential growth of cells of the inner and outer surface of the petals, cell sizes of both surfaces were determined. This was done in areas of the bottom and the upper part of the petals. In the bottom part of the petals there were no significant differences between the treatments on the inner side, as all petals grew. On the outer side growth was measured only in non-stored flowers. Although data were rather scattered, for the upper part of the petals, in the non-stored flowers there was no clear growth of cells of the outer side of the petals while there was an increase in cell area on the inner side (Fig. 6). After storage at 21 kPa O_2 there was no significant growth of the inner cells anymore, however, after storage at 1 kPa O_2 there was a significant increase in average cell sizes. In contrast to non-stored flowers, the data indicated increases in cell sizes on the outer side of petals from 1 kPa O_2-stored flowers.

DISCUSSION

Lowering O_2 partial pressure lowered respiration rate (Fig. 1A) and ethylene production rate (Fig. 3) of rose flowers. Storage at low O_2 partial pressures restored petal growth that was hampered after storage at 21 kPa O_2 (Fig. 4, 6B). From these effects it could be expected that there should be a positive effect on vase life of low O_2 partial

pressures during storage. A positive effect of decreased respiration rate is expected because the flower will use less of its stored carbohydrates. With fresh-cut rose flowers the amount of stored carbohydrates limits full flower development of some cultivars (Kuiper et al., 1995). Cevallos and Reid (2000) calculated a linear relation between respiration rate at storage and length of vase life for narcissus flowers. In a preliminary experiment with storage of 'First Red' rose flowers at 12 °C and 4 °C in air, we found vase lives of respectively 10 d and 12 d. Assuming that a linear relationship between respiration rate at storage and length of vase life exists for rose flowers also and that the Q_{10} of rose flowers is 3 (Reid, 2001b), we estimated the relationship between respiration rate at storage and vase life. From that relationship we concluded that lowering respiration rate at 12 °C to half of its rate will extend vase life by about 1.7 d. Due to the logarithmic response of respiration rate on O_2 partial pressure (Fig. 1A), it may be expected that the partial pressure of O_2 would have to be <2 kPa to significantly effect vase life. However, we did not find a significant difference in length of vase life between storage at 21 kPa O_2 and at 6, 2, 1 or 0.5 kPa. In the range of O_2 partial pressures <2 kPa the RQ increased to levels far above 1, due to an increase in CO_2 production rates, indicating substantial anaerobic respiration, which is rather negative for an efficient energy balance and could result in harmful end products (e.g. ethanol, acetaldehyde).

Besides length of vase life, quality aspects such as flower opening are important issues. Rapid elongation growth of petals is a prerequisite for flower opening in many species. Also opening of rose flowers is accompanied by a large increase in petal cell size (Berkholst, 1981). Dry storage negatively affected petal enlargement, but this negative effect was partly nullified by low O_2 during storage (Fig. 4). Nevertheless, flower opening was hampered after dry storage at low O_2 partial pressures (Table 1, Fig. 3). This was due to the absence of curling of the upper part of the petals. Change in petal orientation during flower opening can be the result of differences in cell expansion between inner and outer petal surfaces (Wood, 1953; Tanaka et al., 1988, Bieleski et al., 2000). Our results indicate that rose petals also reflex outward due to differences in cell expansion between inner and outer petal surfaces (Fig. 6, non-stored). After dry storage, an increase in inner petal cell sizes could not be measured anymore. This agrees with the inhibition of growth measured for the entire petal (Fig. 4). Absence of curling at the upper part of the petals after low O_2-storage seems not to be caused by cessation of cell enlargement, but by growth from the inner as well as from the outer cells (Fig. 6). This agrees with the idea that low O_2 has a positive effect on growth of the entire petal (Fig. 4). How O_2 partial pressure affects cell enlargement and more specifically differential cell growth of outer and inner petal surfaces is unknown. It is interesting that inhibition of (very low) ethylene production occurs at low O_2 (Fig. 2). A possible role of ethylene in gravitropism, another phenomenon related to differential cell enlargement, is mentioned in the literature (Golan et al., 1996; Philosoph-Hadas et al., 1996; Madlung et al., 1999).

We conclude that there are no positive effects of low oxygen partial pressures during storage at 12 °C in 'First Red' cut rose flower. In the 'Produce Facts' of the Post-harvest Technology Research and Information Center, University of California (http://postharvest.ucdavis.edu/Produce/ProduceFacts/) CA is mentioned to be beneficial for anthurium and carnation flowers. Anthurium is a chilling-sensitive flower that cannot be stored at low temperatures and in which flower opening is not important, whereas carnation is very sensitive to endogenous ethylene. The positive effect of MAP reported for mini-gladiolus spikes (Meir et al., 1995) seems to be related to retardation of senescence of the vegetative parts which served as source for assimilates. It is likely that positive effects of modified atmospheres only occur for particular flowers and that responses will be due to the specific nature of the cut flower.

Literature Cited
Berkholst, C.E.M. 1981. Cell size in rose petals, an indicator for quality of vase life. Acta Hort. 181:339-344.
Bieleski, R., Elgar, J. and Heyes, J. 2000. Mechanical aspects of rapid flower opening in Asiatic lily. Ann. Botany 86:1175-1183.
Cevallos, J.C. and Reid, M.S. 2000. Effects of temperature on the respiration and vase life of *Narcissus* flowers. Acta Hort. 517:335-341.
Golan, A., Tepper, M., Soudry, E., Horwitz, B.A. and Gepstein, S. 1999. Cytokinin, acting through ethylene, restores gravitropism to Arabidopsis seedlings grown under red light. Plant Physiol. 112:901-904.
Goszczynska, D.M. and Rudnicki, R.M. 1988. Storage of cut flowers. Hort. Rev. 10:35-62.
Kuiper, D., Ribot, S., Van Reenen, H.S. and Marissen, N. 1995. The effect of sucrose on the flower bud opening of 'Madelon' cut roses. Scientia Hort. 60:325-336.
Madlung, A., Behringer, F.J. and Lomax T.L. 1999. Ethylene plays multiple nonprimary roles in modulating the gravitropic response in tomato. Plant Physiol. 120:897-906.
Meir, S., Philosoph-Hadas, S., Michaeli, R., Davidson, H., Fogelman, M. and Schaffer, A. 1995. Improvement of the keeping quality of mini-gladiolus spikes during prolonged storage by sucrose pulsing and modified atmosphere packaging. Acta Hort. 405:335-342.
Philosoph-Hadas, S., Meir, S., Rosenberger, I. and Halevy, A.H. 1996. Regulation of the gravitropic response and ethylene biosynthesis in gravistimulated snapdragon spikes by calcium chelators and ethylene inhibitors. Plant Physiol. 110:301-310.
Reid M, 2001a. Advances in shipping and handling of ornamentals. Acta Hort. 543:277-284.
Reid M, 2001b. Summary of CA and MA requirements and recommendations for cut flowers. CA Bibliography (1981-2000) and CA recommendations (2001); Postharvest Hort. Series No. 22 (on CD-ROM), Postharvest Technol. Res. Inform. Center. U. California, Davis, USA.
Tanaka, O., Tanaka, Y. and Wada, H., 1988. Photonastic and thermonastic opening of capitulum in dandelion, *Taraxacum officinale* and *Taraxacum japonicum*. Bot. Mag. Tokyo 101:103-110.
Wood W.M.L., 1953. Thermonasty in tulip and crocus flowers. J. Exp. Bot. 4:65-77.

Tables

Table 1. Diameter of flowers after 3 and 12 days of vase life, following 5 days storage at 12 ^{o}C in different partial pressures of O_2.

O_2 partial pressure	Diameter (mm)	
(kPa)	Day 3	Day 12
0.5	45.5	54.0
1	56.5	68.4
2	55.0	66.0
6	61.7	70.6
21	66.5	72.9
LSD	6.7	8.0

Figures

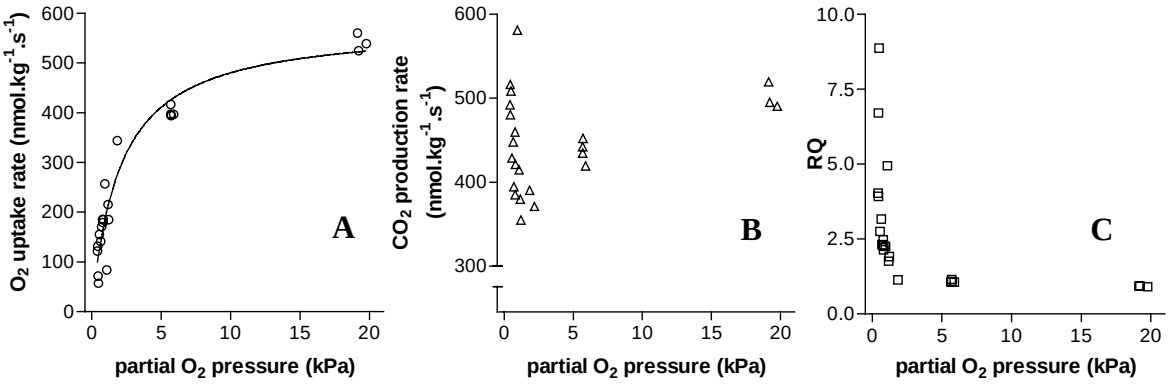

Fig. 1. O_2 uptake (A), CO_2 production rate (B) and R(espiratory) Q(uotient) (C) of rose flowers stored at 12 °C under different O_2 partial pressures.

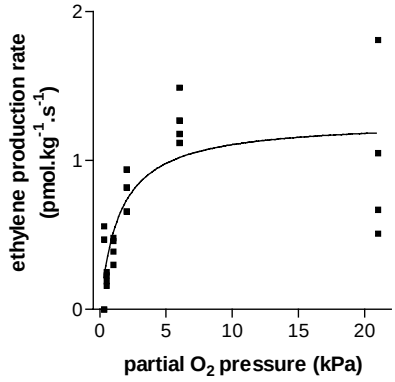

Fig. 2. Evolution of O_2 partial pressure on ethylene production rate.

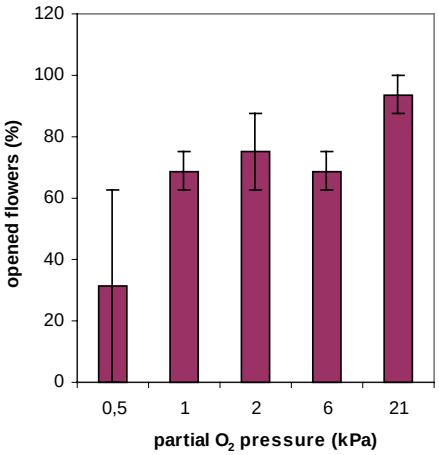

Fig. 3. Influence of [O_2] during 5 d storage on flower opening during subsequent vase life. Bars indicate SEM.

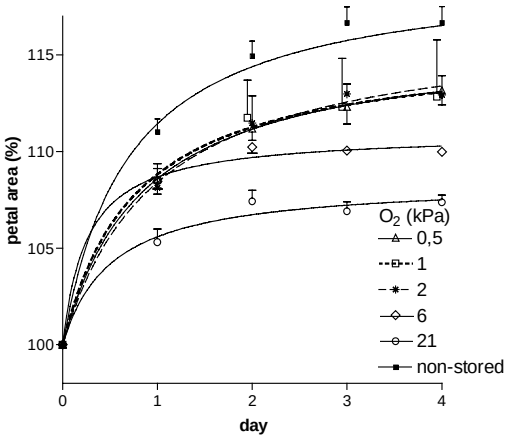

Fig. 4. Increase of outer petals taken from the flowers immediately after storage and placed in water, due to [O_2] during 5 d storage. Bars indicate half of the SEM.

Fig. 5. Representative flower after 5 days of vase life following 5 d-storage at 1kPa O_2.

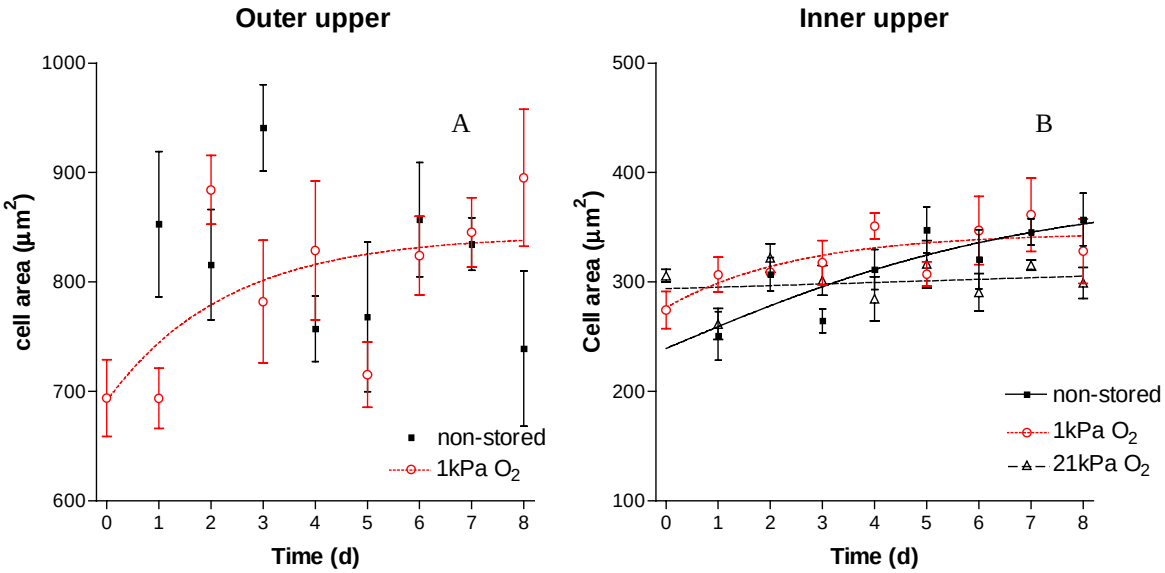

Fig. 6. Average cell size (area) on the upper part of an outer petal during vase life after different storage conditions, measured at the outer (A) and inner (B) side of the petal. Bars indicate SEM.