Responses of cut carnations to a low oxygen level in the ambient atmosphere

J. GOLIÁŠ, F. KOBZA

Mendel University of Agriculture and Forestry, Brno, Faculty of Horticulture, Lednice, Czech Republic

ABSTRACT: Carnation (*Dianthus caryophyllus* L.) flowers were subjected to low oxygen to investigate the physiological effects on flower senescence. The effect of ultra low oxygen (0.6–0.8%) led to low accumulation of ethanol that amounted to 8 mg/l in the tissue pulp in 19 days. The content of acetaldehyde showed an exponential decrease in its previous value after a subsequent exposition of cut carnations to air but still at a cold storage temperature. The content of sugars such as sucrose, glucose and fructose linearly decreased with small differences between ULO and RA conditions. The sucrose content was at a trace concentration. Visual symptoms of injury were observed in ULO conditions after 19 days of storage when brown spots appeared at the top of petals.

Keywords: *Dianthus caryophyllus* L.; low oxygen atmosphere; ethanol; acetaldehyde; sucrose; glucose; fructose

Each postharvest physiological or handling step has a potential to either maintain or reduce the quality of fresh cut flowers. The undesirable postharvest changes that occur during the storage of fresh flowers (wilting, senescence) can be delayed through elevated carbon dioxide and lowered oxygen in storage atmosphere. In typically ultra low oxygen atmosphere used for cut flowers, the content of oxygen is critical for optimising the gaseous mixture just above inducing the fermentative metabolism. However, if fresh flowers are exposed to stress oxygen and/or higher CO_2 level for a period longer than the time span they usually tolerate, detrimental effects like abnormal petal colour and accumulation of ethanol and acetaldehyde occur. Elevated CO_2 atmosphere treatment of cut white carnation flowers for 3 days at 0°C and 20°C caused a transient yellowing of petals upon removal from 60% CO_2 atmosphere at 20°C (IRVING, HONNOR 1994).

Various physiological and storage studies were conducted aimed at the role of ethylene production and sensitivity in senescence (WU et al. 1991a,b; STABY et al. 1993; BRANDT, WOODSON 1992), and the climacteric peak of ethylene production (LEE et al. 1990). No morphological changes symptomatic of floral senescence appeared in flowers treated with aminotriazole and longevity was extended (ALTMAN, SOLOMOS 1993). The possible inhibitory effect of silver as silver thiosulphate on ethylene synthesis of cut carnations to extend their vase life (VEEN 1979; GORIN et al. 1981; VEEN, GEIJN 1978; GORIN et al. 1985) was evaluated. Gaseous compounds such as 1-methylcyclopropene appear to block the ethylene receptor and inhibit the responses of plants to ethylene (SISLER, SEREK 2001).

A continuous treatment with ethanol decreased the sensitivity of flowers to exogenous ethylene and doubled the vase life of carnation flowers (WU et al. 1992).

The objective of this study was to investigate the effect of low O_2 atmosphere alone, without elevated carbon dioxide, on ethanol and acetaldehyde content in the tissue and on sugar concentration, to better understand the effect of controlled gas mixture on these factors and thus on longevity of carnation flowers during the following storage in ventilated air.

MATERIAL AND METHOD

Set-up of the experiment

Carnation flowers were harvested in a company specialising in greenhouse cultivation in Tvrdonice, and transported in an air-conditioned vehicle to Mendel University of Agriculture and Forestry, Faculty of Horticulture in Lednice. The cut flowers were put in a cold room into 200L containers that were closed after three hours from the time of picking and kept at 0.8% O_2 and 0.1% CO_2 (ULO). The conditions were supervised by an automatic measuring system (Dual analyser TS 12, Arelco, France) at the intervals of 1 hour for both gases. Flowers in the air (RA) atmosphere were stored in water solution at the same temperature. For quality checks, the flowers were removed from the containers on the 7^{th} and 13^{th} days for the analysis of anaerobic metabolites (ethanol and acetaldehyde). The containers were opened after 19 days, and after that both variants were stored at the same temperature and in the same gas mixture.

Supported by the Ministry of Education, Youth and Sports of the Czech Republic (Grant No. MSM 435100002).

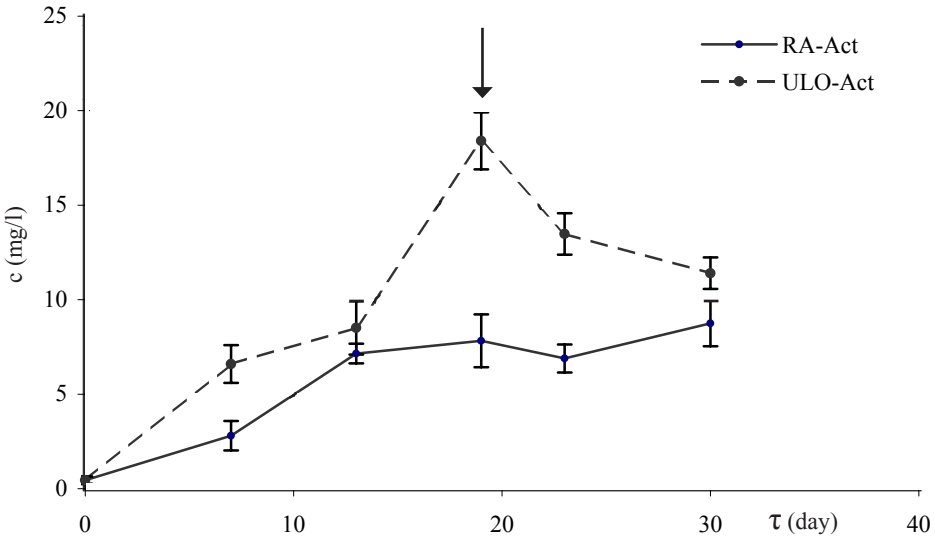

Fig. 1. The time pattern of acetaldehyde concentration (Act) in the ambient atmosphere under ultra low oxygen (0.6–0.8%). This phase lasted for 19 days, subsequently the flowers were stored at cold storage temperature in normally composed air. Regular atmosphere RA (21% O_2 and 0.03% CO_2) was used the whole time at cold storage temperature. Each value represents 3 flowers and vertical bars indicate SE, $P < 0.05$. The arrow indicates the transfer to air

Objective characteristic of the bud opening stage

On the whole, bud opening is a continuous process. For setting the relations that determine each stage, the opening process was decomposed into a sequence of stages starting with stage I (fully closed bud) to stage VII (totally opened flower) after CAPS et al. (1980).

Determination of anaerobic metabolite content

Ethanol and acetaldehyde in frozen pulp were analysed by GC (column packed with Porapak P). 1 µl of aqueous sample was injected into a sample block fitted with Teflon, an inert material. Four peaks on the chromatogram were evaluated, two of them quantified with an external standard of these compounds (acetaldehyde and ethanol) and expressed in mg/l for each of them.

Determination of sugar content

From homogenised frozen pulp, sugars (sucrose, glucose, fructose) were analysed by HPLC of aqueous extract (IEX H^+ form, 8 µm, water as mobile phase, refractometric detector, Watrex). Sugars were quantified with external standards and expressed in g/l for each compound.

Estimation of quality attributes

A typical loss of floral petal colour was assessed by visual inspection using a 4 grade system (0 = absent, 1 = little, 2 = moderate and 3 = severe). Quality inspection was carried out immediately after the removal from ULO conditions and after a shelf period of 30 days.

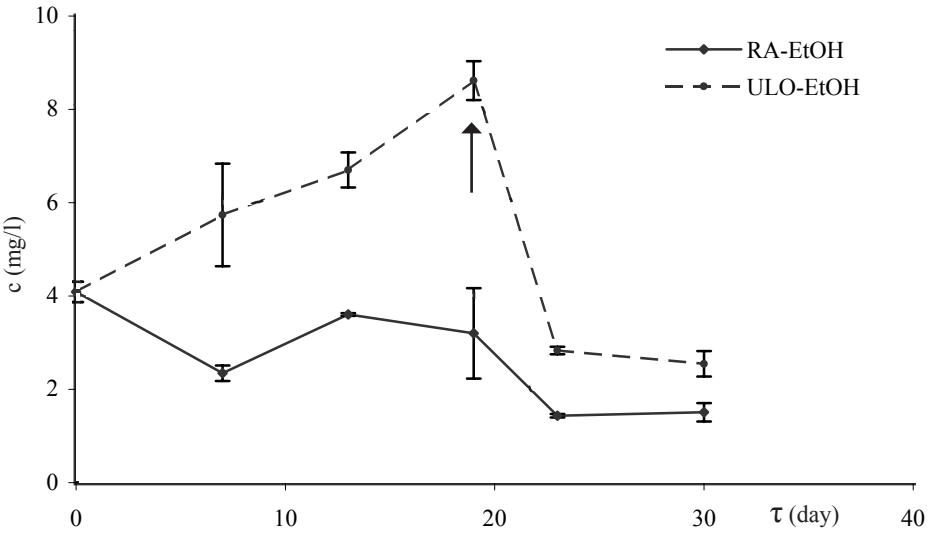

Fig. 2. The concentration of ethanol (EtOH) in carnation flowers that were first stored 19 days in ULO conditions (0.6–0.8% O_2 and 0.1% CO_2) and them in normally composed air. Regular atmosphere RA (21% O_2 and 0.03% CO_2) was used the whole time at cold storage temperature. Each value represents 3 flowers and vertical bars indicate SE, $P < 0.05$. The arrow indicates the transfer to air

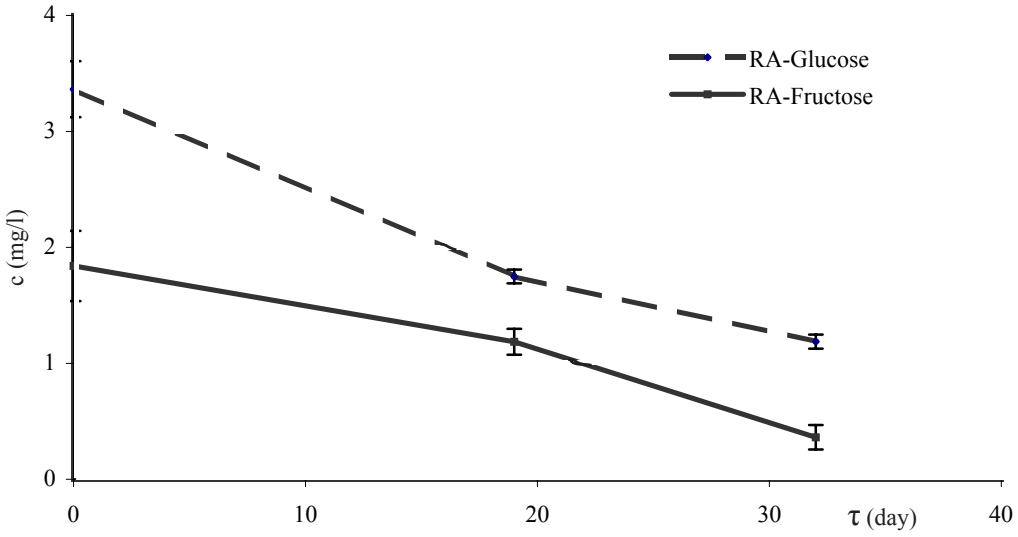

Fig. 3. The concentration of glucose and fructose in cut flower tissue stored in regular atmosphere RA (21% O_2 and 0.03% CO_2). Each value represents 3 flowers and vertical bars indicate SE, $P < 0.05$

Statistical analyses

Six replications were provided for measurement of anaerobic metabolites and three replications for sugar content, the means and standard errors being reported in figures.

RESULTS AND DISCUSSION

Quality evaluation of stored flowers

Carnation flowers were harvested at incipient stage II as indicated after evaluation (CAPS et al. 1980) when the petals of the closed buds start to separate. Exposure to ULO conditions slowed down the opening of buds that consequently did not emerge over the top petals. There were no significant differences in the overall appearance between different treatments of buds with gas mixtures such as ULO and RA atmosphere. In 30 days the flowers were half opened with calyx and corolla diameter tending to be equal.

The deterioration of the external quality was observed in flowers stored in low oxygen. Some injuries were observed after 19 days of storage at ULO conditions. Floral petal colour scored 1 (little colour change), which means that the flowers remained acceptable for visual evaluation in the subsequent period in ventilated air. Visual symptoms of injury were observed in low O_2 but none in regular atmosphere at the temperature around 16°C during the next three days. However, neither storage temperature nor O_2 level brought any further changes in visual quality of cut carnations. IRVING and HONNOR (1994) reported detrimental effects of treatment by 60% CO_2 concentration at 20°C expressed as yellowing of the petals, but claimed no detriment to vase life at 0°C.

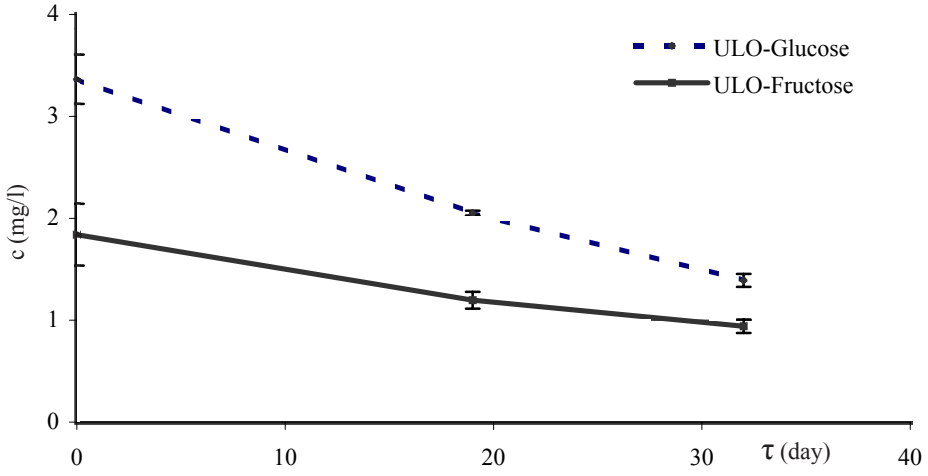

Fig. 4. The concentration of glucose and fructose in cut flower tissue stored in ultra low oxygen (ULO) (0.6–0.8% O_2 and 0.1% CO_2). Each value represents 3 flowers and vertical bars indicate SE, $P < 0.05$

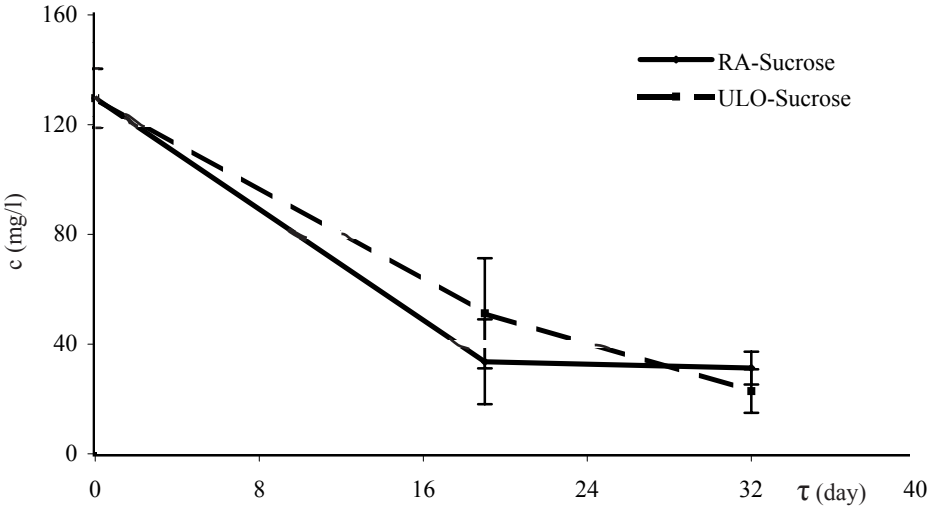

Fig. 5. The concentration of sucrose in cut flower tissue stored in ultra low oxygen (ULO) (0.6–0.8% O_2 and 0.1% CO_2) and regular atmosphere RA (21% O_2 and 0.03% CO_2). Each value represents 3 flowers and vertical bars indicate SE, $P < 0.05$

Accumulation of anaerobic metabolites in the tissue of cut flowers

The increased concentrations of acetaldehyde in lowered oxygen (Fig. 1) are several times higher than in the normal oxygen-containing atmosphere (RA), but the difference did not exceed 20 mg/l. This content is due to the ambient atmosphere without increased CO_2, the accumulation of this metabolite being associated only with oxygen.

The concentration of ethanol in the tissues constantly kept in nearly anaerobic conditions has a linear increase in time during the whole exposition to the low oxygen level (Fig. 2). Consequently, the oxidation of ethanol (as well as of acetaldehyde) in cut flowers exposed to regular oxygen atmosphere is rather low but higher than the corresponding value in flowers that were in regular atmosphere all the time. It could be concluded that the concentration of oxygen at a level of 0.6–0.8% did not physiologically harm the tissues of flowers by producing increased quantities of acetaldehyde and ethanol.

Content of sugars during storage

Sugars can be located mainly in vacuoles rather than in cytoplasm, and thus they can be used for the maintenance of osmotic pressure in the vacuole. WOUTER and VAN DOORN (2001) assumed that water uptake rapidly declines during the vase life and incipient wilting of petals can be delayed by a mechanism whereby sugar is maintained in the vacuole. During storage in gas mixture with low oxygen level the concentration of determined sugars declined (Figs. 3 to 5). For the content of these compounds, the typical time pattern was a linear decrease from the very beginning in both atmospheres. We found little relevance of the content of sugars for flower life.

References

ALTMAN S.A., SOLOMOS T., 1993. 3-amino-1,2,4-triazole prolongs carnation vase life. HortScience, *28*: 202–203.

BRANDT A.S., WOODSON W.R., 1992. Variation in flower senescence and ethylene biosynthesis among carnation. HortScience, *27*: 1100–1102.

CAPS A.M., SALVATOR P.J., IBAŇEZ M.J., 1980. Objective characterisation of type stages in bud opening of carnations (*Dianthus cariophyllus* L.). Acta Hort., *113*: 175–181.

GORIN N., ZONNEVELD H., SPEKKING T., 1981. Quantitative test for silver in cut carnations. HortScience, *16*: 1, 84.

GORIN N., STABY G., KLOP W., TIPPET N., LEUSSING D.L. Jr., 1985. Quality measurements of carnation treatment solutions in relation to flower silver distribution and longevity. J. Amer. Soc. Hort. Sci., *110*: 117–123.

IRVING D.E., HONNOR L., 1994. Carnations: effects of high concentrations of carbon dioxide on flower physiology and longevity. Posth. Biol. Technol., *4*: 281–287.

LEE J.S., SONG E.S., LEE P.D., 1990. Effects of inhibitors of ethylene synthesis and action on ethylene biosynthesis and flower longevity of carnations. J. Korean Soc. Hort. Sci., *31*: 284–293.

SISLER E.C., SEREK M., 2001. New development in ethylene control-compounds interacting with the ethylene receptor. In: NELL T.A., CLARK D.G. (eds.), Proc. VII Int. Symp. on Postharvest Physiology Ornamentals. Acta Hort., *543*: 33–39.

STABY G.L., BASEL R.M., REID M.S., DODGE L.L., 1993. Efficacies of commercial anti-ethylene products for fresh cut flowers. HortTechnology, *3*: 199–202.

VEEN H., GEIJN S.C. VAN DE, 1978. Mobility and ionic form of silver as related to longevity of cut carnations. Planta, *140*: 93–96.

VEEN H., 1979. Effects of silver on ethylene synthesis and action cut carnations. Planta, *145*: 467–470.

WOUTER G., DOORN W.G. VAN, 2001. Role of soluble carbohydrates in flower senescence: A survey. In: NELL T.A., CLARK D.G. (eds.), Proc. VII Int. Symp. on Postharvest Physiology Ornamentals. Acta Hort., *543*: 179–183.

WU M.J., DOORN W.G. VAN, REID M.S., 1991a. Variation in the senescence of carnation (*Dianthus caryophyllus* L.) cultivars. I. Comparison of flower life, respiration and ethylene biosynthesis. Sci. Hort., *48*: 1–2, 99–107.

WU M.J., ZACARIAS L., REID M.S., 1991b. Variation in the senescence of carnation (*Dianthus caryophyllus* L.) cultivars. II. Comparison of sensitivity to exogenous ethylene and of ethylene binding. Sci. Hort., *48*: 1–2, 109–116.

WU M.J., ZACARIAS L., SALTVEIT M.E., REID M.S., 1992. Alcohols and carnation senescence. HortScience, *27*: 136–138.

Received for publication September 6, 2002
Accepted after corrections December 30, 2002

Odezva řezaných karafiátů na nízkou hladinu kyslíku v ambientní atmosféře

ABSTRAKT: Karafiáty *Dianthus caryophyllus* L. byly vystaveny atmosféře s nízkým obsahem kyslíku za účelem zjištění fyziologické odezvy na stárnutí. Účinek atmosféry s nízkým obsahem kyslíku vedl k malé akumulaci etanolu v pletivu, který dosáhl po 19 dnech skladování 8 mg/l. Obsah acetaldehydu klesl, jakmile byly květy vystaveny vlivu normálně kyslíkaté atmosféry, ale stále při chladírenské teplotě. Obsah cukrů (sacharózy, glukózy a fruktózy) lineárně klesal k nižším hodnotám jen s minimálními rozdíly mezi ULO podmínkami a normálně kyslíkatou atmosférou. Obsah sacharózy se nacházel jen ve stopách. Vizuální symptomy poškození byly pozorovány po 19 dnech skladování v ULO podmínkách jako několik hnědých skvrn na špičkách okvětních lístků.

Klíčová slova: *Dianthus caryophyllus* L.; atmosféra s nízkým obsahem kyslíku; etanol; acetaldehyd; sacharóza; glukóza; fruktóza

Corresponding author:

Prof. Ing. JAN GOLIÁŠ, DrSc., Mendelova zemědělská a lesnická univerzita, Brno, Zahradnická fakulta, Ústav posklizňové technologie zahradnických produktů, Valtická 337, 691 44 Lednice, Česká republika
tel.: + 420 519 340 105, fax: + 420 519 340 159, e-mail: golias@mendelu.cz