Food Chemistry 153 (2014) 157–163

Contents lists available at ScienceDirect

Food Chemistry

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

Effect of carbon dioxide enrichment on health-promoting compounds and organoleptic properties of tomato fruits grown in greenhouse

Zhiming Zhang [a,1], Lihong Liu [a,1], Min Zhang [a], Yongsong Zhang [b], Qiaomei Wang [a,*]

[a] Key Laboratory of Horticultural Plant Growth, Development and Quality Improvement, Department of Horticulture, Zhejiang University, Hangzhou 310029, China
[b] Ministry of Education Key Lab of Environmental Remediation and Ecosystem Health, College of Natural Resources and Environmental Science, Zhejiang University, Hangzhou 310029, China

ARTICLE INFO

Article history:
Received 12 September 2013
Received in revised form 7 December 2013
Accepted 11 December 2013
Available online 19 December 2013

Keywords:
CO_2 enrichment
Tomato fruit
Carotenoids
Organoleptic characteristics

ABSTRACT

The objective of the present study was to evaluate the effect of carbon dioxide (CO_2) enrichment on the main health-promoting compounds and organoleptic characteristics of tomato (*Solanum lycopersicum*) fruits grown in greenhouse. The contents of health-promoting compounds, including lycopene, β-carotene, and ascorbic acid, as well as the flavour, indicated by sugars, titrable acidity, and sugar/acid ratio, were markedly increased in CO_2 enrichment fruits. Furthermore, CO_2 enrichment significantly enhanced other organoleptic characteristics, including colour, firmness, aroma, and sensory attributes in tomato fruits. The results indicated that CO_2 enrichment has potential in promoting the nutritional value and organoleptic characteristics of tomatoes.

1. Introduction

In China, tomatoes are often grown in greenhouses, in order to provide early-ripening fruit that meet the demands of consumers. However, the quality of greenhouse tomato, as indicated by characteristics such as colour and flavour, as well as content of ascorbic acid and carotenoids, is usually found to be poor. Many complaints about poor quality of tomato fruit have been made in the past few years (Baldwin, Scott, Shewmaker, & Schuch, 2000), and consumers demand products with better flavour (Baldwin et al., 2000; Causse, Buret, Robini, & Verschave, 2003).

Several studies have reported that lower carbon dioxide (CO_2) is one of the primary factors affecting the quality of greenhouse tomato. It is considered that the optimal concentration of CO_2 for plant growth is 800–1000 $\mu L\ L^{-1}$ (Kläring, Hauschild, Heißner, & Bar-Yosef, 2007; Jin, Du, Wang, Condon, Lin, & Zhang, 2009). However, the CO_2 concentration in greenhouse is only 100–250 $\mu L\ L^{-1}$ during the daytime due to the hermetic conditions, which impair plant growth (Kläring et al., 2007). Jin et al. (2009) recently proposed a new strategy of CO_2 enrichment by composting crop residues and animal manures directly in the greenhouse. It is profitable for farmers as it requires only low-cost inputs, and avoids the possible environmental problems caused by burning and practices of disposal of these agricultural by-products. The application of this CO_2 enrichment technology increased the production of five leafy and stem vegetables, including celery, leaf lettuce, stem lettuce, oily sow thistle, and Chinese cabbage (Jin et al., 2009).

To our knowledge, CO_2 is the substrate for photosynthesis and its concentration impacts on plant growth. Previous studies have demonstrated the beneficial influence of CO_2 on photosynthetic rate, plant growth and crop yield (Ainsworth & Long, 2005; Sanz-Sáez, Erice, Aranjuelo, Nogués, Irigoyen, & Sánchez-Díaz, 2010). A report studied the effect of CO_2 enrichment on quality of tomatoes (Islam, Matsui, & Yoshida, 1996), but the authors did not check the changes in aroma and carotenoid content of tomato fruits at different maturity stages under CO_2 enrichment treatment. In order to provide consumers with high quality tomatoes, different post-harvest treatments were applied to maintain the antioxidant potentials, as well as the content of lycopene and β-carotene in tomato fruits (Abushita, Daood, & Biacs, 2000; George, Kaur, Khurdiya, & Kapoor, 2004).

Few reports have focused on the effects of cultivation and management on health-promoting compounds and organoleptic characteristics of tomato fruits. The aim of the present study was to examine the effect of CO_2 enrichment on the main health-promoting compounds and organoleptic characteristics, especially the changes in carotenoids and aroma of tomato fruits grown in the greenhouse.

* Corresponding author. Address: Department of Horticulture, Zhejiang University, 866 Yuhangtang Road, Hangzhou, Zhejiang 310058, China. Tel.: +86 571 8590 9333; fax: +86 571 88982278.
E-mail address: qmwang@zju.edu.cn (Q. Wang).
[1] These authors contributed equally to this work.

0308-8146/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.foodchem.2013.12.052

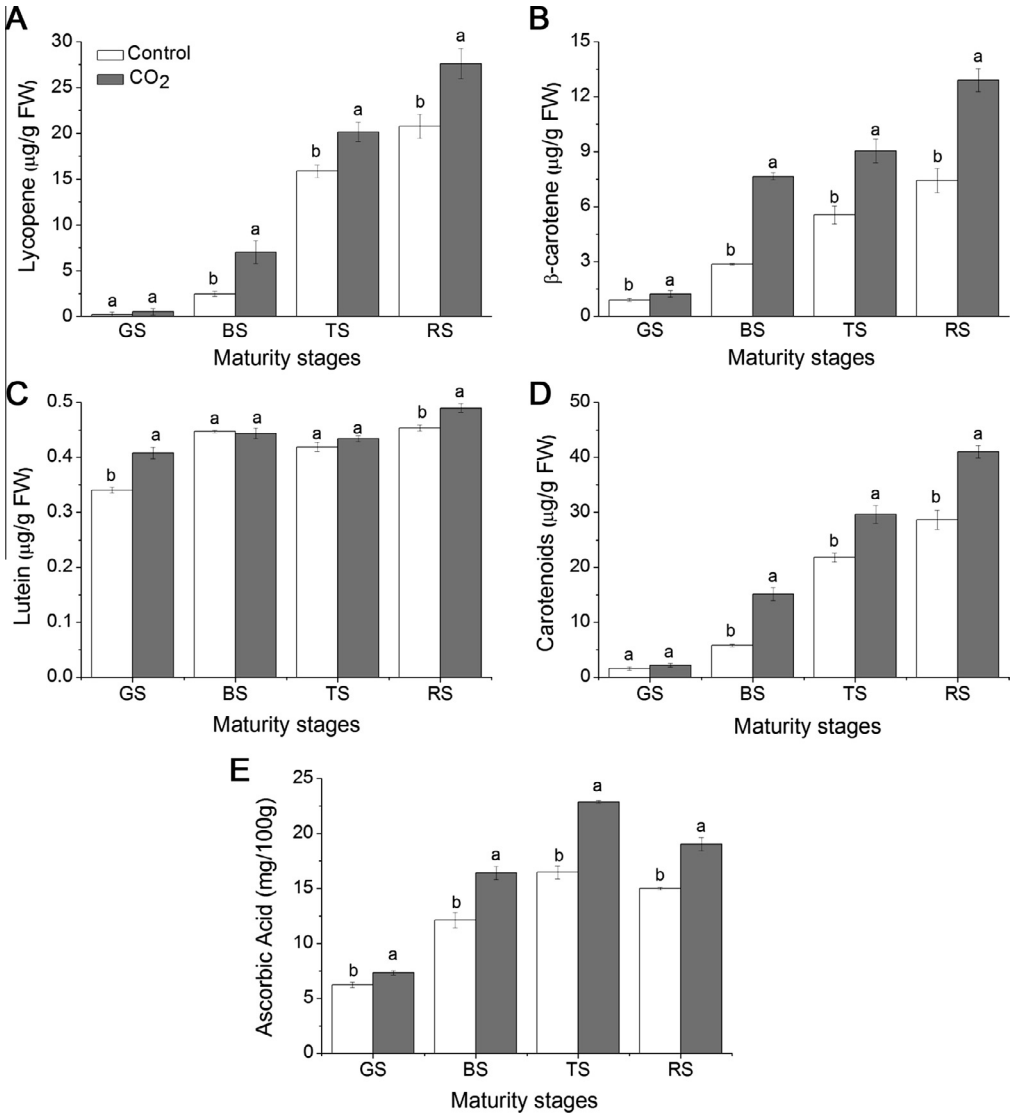

Fig. 1. Effect of CO_2 enrichment on the contents of lycopene, β-carotene, lutein, carotenoids, and ascorbic acid in tomato fruits at four maturity stages. Data are means of three replicates composed of six tomatoes each. Vertical bars represent standard deviation of the mean. Values not sharing a common letter indicate significant difference at $p < 0.05$. GS, mature green stage; BS, breaker stage; TS, tuning stage; RS, mature red stage.

2. Material and methods

2.1. Material and treatment

The study was carried out on tomatoes (*Solanum lycopersicum* cv. Jinpeng) harvested from the experimental greenhouses (lat. N30°45′13″, long. E120°3′9″, Pinghu, Zhejiang Province, China). The experiment was conducted in parallel using two neighbouring greenhouses with dimensions of 12 m (length) × 6 m (width) × 3 m (height) and the same facilities. A composting unit (Jin et al., 2009) producing 800–900 μL L^{-1} CO_2 was placed in the centre of the treatment greenhouse.

Tomato plants were planted at a density of 2.6 plants m^{-2} on 4 January 2011 through routine management. After anthesis, flowers were tagged and fruits were harvested at four different stages, i.e., mature green stage (GS), completely green skin and reaching the standard of commerce; breaker stage (BS), yellow or pink <10%; turning stage (TS), 60–90% pink or red skin; mature red stage (RS), 100% fully red skin. Forty fruits of control and CO_2 enrichment at each stage were selected and divided into four groups for the measurement of colour, firmness, aroma and sensory, and all these fruits were maintained at 20 °C and 95% RH during the test. Then three replicates of six fruits each were used in chemical analysis.

2.2. Carotenoids

Tomatoes (3 g) were homogenised for 30 min in an extraction solution (30 ml ethanol: acetone: *n*-hexane (1:1:1) containing 1% BHT and added 10 ml distilled water, then centrifuged for 10 min. The supernatant was immediately subjected to rotary evaporation under vacuum at a maximum of 30 °C. A mixture (tetrahydrofuran: acetone: methanol = 15:30:55) was added to capture remaining water and assist in the transfer of lipophilic carotenoids. This procedure was repeated three times, until all pigments were extracted from the tissue. Extracts were then bulked together and stored at −20 °C prior to analysis. Standard precautions were taken throughout to prevent exposure of carotenoids to light, oxygen, acid and heat by working in dim light and with autoclaved labware. Carotenoids were analysed by using high-performance liquid chromatography (HPLC) with UV detection at 475 nm. Samples (20 μl) were injected onto a C18 reverse-phase column. The mobile phase (1.2 ml/min) consisted of solution