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Physiological responses and quality attributes of 'Kyoho' grapes to controlled atmosphere storage

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Abstract

This research studied the physiological responses and quality attributes of Kyoho grapes (*Vitis vinifera X V. labrusca*) to controlled atmosphere storage. The grapes were stored for up to 60 days in 95% relative humidity with four different conditions, 4% O_2 + 9% CO_2, 4% O_2 + 30% CO_2, 80% O_2, and air, as control. The examined physiological responses and quality attributes included polyphenol oxidase (PPO) activity, ethanol concentration, fruit detachment force (FDF), firmness, color, soluble solid content (SSC), titratable acidity (TA), ascorbic acid concentration (Vc), and sensory quality. PPO activity, FDF drop and decay incidence when stored in 4% O_2 + 30% CO_2 were more effectively controlled, but unacceptable alcoholic flavor and browning were detected after 45 days, compared with those stored in 4% O_2 + 9% CO_2 or 80% O_2. The fruits kept in 4% O_2 + 9% CO_2 or 80% O_2 had good quality during 60 days of storage. The results suggested that high O_2 atmosphere exhibited a potential for maintaining the quality of 'Kyoho' grapes during long-term storage.

Keywords: 'Kyoho' grapes; O_2 and CO_2 concentrations; Controlled atmosphere; Physiology; Quality

1. Introduction

'Kyoho' grape is a cross between *V. vinifera* and *V. labruscana* grapes. The variety, famous for its large-sized berry and excellent taste, is an economically important grape cultivar in China. Harvested grapes deteriorate rapidly without appropriate treatments, and deterioration is mainly characterized by rachis browning, fungal rot, berry drop, softening, moisture loss, and off-flavor (Nelson, 1978; Wu, Ren, & Hua, 1992). Especially, berry drop, browning, and decay are the main limitations to market acceptance of 'Kyoho' grapes (Lv, Xiu, & Ma, 1994).

In China, the most common commercial method to control deterioration of grapes is a combination of SO_2 treatment with cold storage (Lv et al., 1994). Nevertheless, excessive SO_2 is injurious to rachis and berries, causes corrosion of metals, and can be dangerous to people allergic to sulfite residues (Smilanick et al., 1990). Therefore, alternative techniques for quality control of harvested grapes are needed because of concerns for food safety and restrictions in the use of chemicals.

Controlled atmosphere (CA) with high CO_2 could be effective in maintaining quality and extending shelf life of fruits and vegetables (Beaudry, 1999). Physiological responses and quality changes of many grape varieties have been investigated under high CO_2 atmosphere storage (Ahumada, Mitcham, & Moore, 1996; Crisosto, Garner, & Crisosto, 2002; Guan, Zhang, Xiu, & Yan, 2002; Artés-Hernández, Aguayo, & Artés, 2004). As yet, little information is available on the tolerance of 'Kyoho' grapes to high O_2 levels. In recent years, high O_2 treatment has been considered to be an effective

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means for inhibiting enzymatic discoloration, anaerobic fermentation reactions, and aerobic and anaerobic microbial growth (Day, 1996). There have been studies on the effects of high O_2 levels on the physiology and quality of produce such as iceberg lettuce (Heimdal, Kuhn, Poll, & Larsen, 1995), apples (Lu & Toivonen, 2000), loquat fruits (Zheng, Su, Li, Li, & Xi, 2000), litchi (Duan et al., 2004), and strawberries (Wszelaki & Mitcham, 2000; Van der Steen, Jacxsens, Devlieghere, & Debevere, 2002). However, there are no published reports on the effects of high O_2 atmospheres on physiology and quality of grape fruits.

The aims of this research were to investigate the physiological responses and quality attributes of 'Kyoho' grapes under high O_2 or high CO_2 atmospheres during long-term storage, and to identify the feasibility and possible benefits of high O_2 treatment in comparison with air and CA in high CO_2 levels.

2. Materials and methods

2.1. Fruits

'Kyoho' table grapes (*Vitis vinifera X V. labrusca*), cultivated in a greenhouse, were harvested at commercial maturity stages from the vineyard of the Shanghai Grape Research Institute in Shanghai, China. The fruits were transported to the Laboratory of Cold Chain Research at Shanghai Jiao Tong University under refrigerated conditions (at 10 °C) within 2 h. The clusters were selected on the basis of uniform color, size, firmness, and absence of blemishes or disease, and precooled (4 °C, 14 h) immediately upon arrival.

2.2. Storage conditions

Storage conditions were as follows: air (control), 4% O_2 + 9% CO_2, 4% O_2 + 30% CO_2, and 80% O_2. Four CA chambers (105 cm × 55 cm × 100 cm) with four CO_2 absorbers (soda lime with ethyl violet as an indicator) and four ethylene absorbers were connected to an atmosphere analyser (GAC 1100, Italy). Initial O_2 and CO_2 levels in the chambers were established by the control of N_2 flow rate generated by cellulose membrane and CO_2 via pressure regulators. There were eight cartons of table grapes (about 5 ± 1 kg/carton) in each CA chamber. All the treatments were kept at 0 ± 1 °C in approximately 95% relative humidity. The samples were assayed and analysed at 15-day intervals during the 60 days of storage.

2.3. PPO activity assay

Polyphenol oxidase (PPO) activity was measured as described by Jing and Ding (1981) with some modifications, and expressed as oxidation Vc μmol min^{-1} g^{-1} FW. A ground sample of 2 g berry flesh was transferred to 100 ml volumetric flask, quantified to 100 ml with distilled water, and homogenized. Then 10 ml homogenized suspending liquid was imbibed and transferred to a 250 ml triangular flask. Subsequently, the reagents were added to this triangular flask according to the following order: 1 ml phosphoric acid buffer (pH 6.4), 5 ml of 0.02 g/l catechol solution, and 5 ml ascorbic acid solution (0.4 mol/l). The mixture was agitated in a thermostatic vibrator (THZ-82A, Shanghai Yuejin Medical Instrument Co., Ltd., Shanghai) at 20 °C for 2 min; 5 ml of 0.5 g/l metaphosphoric acid solution was added immediately in order to stop the reaction in mixture. After the addition of 1 ml of 0.05 g/l starch solution, the procedure of titration with 0.01 mol/l KIO_3 was stopped until the blue color in the mixture remained. The amounts of KIO_3 were calculated. All measurements were conducted in triplicates unless specified.

2.4. Determination of ethanol concentration

Ethanol contents in berry flesh were determined according to the Oxidation–Reduction Titration method (Liu & Kou, 1998). Fresh berry flesh (~20 g) was homogenized in a blender, and then transferred to a retort with 150 ml distilled water for thermostatic distillation at 100 °C. A sample of 5 ml ethanol distillate was transferred into a triangular flask containing $K_2Cr_2O_7$ and concentrated H_2SO_4 for circulating distillation for 20 min. After cooling, $Na_2S_2O_3$ was used for titration and the ethanol contents could be calculated. There were three replicates for each analysis per treatment.

2.5. Measurement of fruit detachment force (FDF)

The FDF between stem and berry was measured using a TA-XT2i texture analyser (Stable Micro Systems, Ltd., UK) with slight modifications. An individual grape stem was passed through a hole of a homemade plastic base and firmly clamped with a spring clamp. The spring clamp was fastened to the load cell fixture. The texture analyser was programmed so that upward movement was perpendicular to the longitudinal axis of the stem–berry system until they were pulled apart. The maximum force encountered was recorded during the tension test. A speed of 2 mm/s was set for the test and 5 mm/s for both pre- and post-tests. Trigger force was 5 g. Forty berries with stems from each treatment were measured.

2.6. Physical and chemical quality attributes analysis

Berry firmness is calculated as the first force peak on fruit Texture Profile Analysis (TPA) curve. TPA were