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Effects of nitrous oxide (N_2O) treatment on the postharvest ripening of banana fruit

Xavier Palomer, Irma Roig-Villanova, Désirée Grima-Calvo, Miquel Vendrell *

Departament de Genètica Molecular, Institut de Biologia Molecular de Barcelona (IBMB-CSIC), Jordi Girona 18-26, 08034 Barcelona, Spain

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Abstract

The effect of nitrous oxide (N_2O) alone or in combination with reduced oxygen (O_2) levels on the postharvest ripening of mature green banana fruit was investigated. Banana fruit stored at 20 °C were exposed, in a flow-through system, to 20, 40, 60 and 80% N_2O with 8–20% O_2 for 2, 3, 5 and 10 days, as well as in continuous treatments, and compared to control samples. Our results showed that fruit ripening was significantly delayed by N_2O, as judged by both ethylene synthesis and respiration associated with changes in the colour, acidity and softening. This response to N_2O was dose- and time-dependent. The delay of ripening by N_2O was not detectable at 20% concentration, but steadily rose at increasing concentrations above 40%. However, its effects on ripening appeared to be saturated at 80% N_2O. Combinations of N_2O with low O_2 (8 and 12%) controlled atmospheres had a synergic effect on the ripening-delay capacity of the former. The capability of N_2O to slow down fruit ripening is thought to be due to its anti-ethylene activity, as suggested by the delay in the climacteric associated rise in ACC oxidase activity. Furthermore, N_2O treatments did not cause any great change in the quality parameters assessed, except fresh weight loss, which was dependent on the length of the preclimacteric lag period. Thus, our results show that N_2O treatments extend the storage life of banana fruit without any adverse effect on physico-chemical quality, and therefore, have the potential to control postharvest ripening of banana fruit during handling, transportation and storage.

Keywords: *Musa acuminata*; Nitrous oxide; ACC oxidase

1. Introduction

Banana (*Musa acuminata* L.) is a climacteric fruit in which the postharvest physiology is characterized by a preclimacteric phase followed by a burst in ethylene production that signals the beginning of the ripening. In addition, there is a sharp and intense rise in the respiration activity of the fruit. Other changes that occur during banana fruit ripening include fruit softening, a

Abbreviations: ACC, 1-aminocyclopropane-1-carboxylic acid; ACO, ACC oxidase; ACS, ACC synthase; CA, controlled atmosphere; mACC, malonyl-conjugated ACC

* Corresponding author. Tel.: +34 93 4006126; fax: +34 93 2045904.
E-mail address: mvmagr@cid.csic.es (M. Vendrell).

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massive conversion of starch to sugars in the pulp, a decline in polyphenols, synthesis of aroma compounds and de-greening of the peel (Clendennen and May, 1997).

Banana fruit can be collected at a wide range of physiological ages, from half grown to fully grown, and be of excellent quality after ripening with the application of ethylene. However, those fruit that ripen too early once collected are easily damaged during transport and produce endogenous ethylene which can adversely affect other commodities. The techniques used to delay and manage ripening include: cold storage, controlled atmosphere (CA) storage, ethylene removal, and inhibition of ethylene action through chemical means. Currently, bananas are precooled to 13 °C during transportation to slow down fruit metabolism and therefore delay ripening-onset and senescence. However, this is costly, and fruit rewarm rapidly on the display shelves, thereby reducing shelf life (Klieber et al., 2002). CA storage can extend the shelf life of fruit by decreasing metabolism and suppressing postharvest decay. In preclimacteric bananas, low oxygen concentration (2.5% O_2) slows respiration, peel de-greening and changes in sugars (Kanellis et al., 1989), and minimises the susceptibility of bananas to crown rot (Marchal, 1998). The effectiveness of low oxygen CA in delaying fruit ripening increases with decreasing oxygen concentration as long as the oxygen partial pressure does no drop below the level that engenders anaerobic fermentation, which may affect aromatic quality (Agillon et al., 1987; Solomos and Kanellis, 1997).

Anti-ethylene compounds specifically acting on the synthesis or action of ethylene have also been reported as a very promising research tool. Nitrous oxide (N_2O) is a naturally occurring atmospheric gas principally produced by aerobic denitrifying bacteria in soil, which has been demonstrated to inhibit ethylene action and synthesis in higher plants (Frontiera et al., 1994; Gouble et al., 1995; Leshem and Wills, 1998). N_2O, like CO_2, has an isosteric linear structure that confers similar physical properties such as relative stability and high solubility to both molecules (Leshem and Wills, 1998; Benkeblia and Varoquaux, 2003). This biophysical similarity of N_2O to CO_2 might be pertinent to the control of ethylene in the controlled atmosphere storage of postharvest climacteric fruit (Leshem and Wills, 1998). In addition, N_2O is not toxic, is used in medical practice as an anaesthetic (Gouble et al., 1995), and is a permitted additive for food (Benkeblia and Varoquaux, 2003).

The beneficial effects of N_2O on horticultural produce have already been reported for the climacteric fruit tomato and avocado (Gouble et al., 1995), as well as onion (Benkeblia and Varoquaux, 2003). Other studies reporting the inhibition of postharvest decay of fruit by N_2O have also been carried out in the non-climacteric strawberry and mandarin, and in the climacteric fruit apple, persimmon and tomato (Qadir and Hashinaga, 2001). However, more information is required on the number of fruit and vegetables that may respond to N_2O. The main objective of this research was to determine the effect of a wide range of N_2O concentrations on the storage life of banana fruit. The effect of N_2O on the respiration rate and ethylene production during banana fruit ripening, as well as their consequences on fruit quality parameters, have been investigated.

2. Material and methods

2.1. Plant material

Preclimacteric green banana fruit (*Musa acuminata* L. cv. Dwarf Cavendish) grown in open fields in the Canary Islands were shipped at 13 °C following commercial routes to the laboratory in the Institut de Biologia Molecular de Barcelona. Fruit were sorted for absence of visual defects and uniformity of weight and size in the developmental stage before being used in these experiments. Each banana hand was separated into individual fingers, which were then dipped for 3 min in fungicide solution (1 g/L Benlate®, 3 g/L Dithane® and 250 μl/L Tween® 80) and allowed to air dry. Matched fruit were randomly allocated into different lots for the subsequent treatments and placed at 20 °C into sealed glass jars, where they ripened naturally. One to three fruit were allocated into each jar, and at least 12 fruit were used for each treatment. All fruit were held in a flow-through system and treated with continuous water-saturated air flow at 1–2 L h^{-1} per fruit. Air flows were adjusted to maintain CO_2 levels below 0.2%.

2.2. N_2O treatment of banana fruit

N_2O, N_2 and O_2 cylinders were obtained from Carburos Metálicos S.A. Several N_2O treatments were