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Influence of low oxygen and high carbon dioxide on shredded Galega kale quality for development of modified atmosphere packages

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Abstract

Respiration rate, sensory attributes, colour alterations, and water, chlorophyll and ascorbic acid contents were monitored during storage of shredded Galega kale (*Brassica oleracea* var. *acephala* DC.) at 20 °C to define an adequate range of O_2 and CO_2 partial pressures for product preservation. Different low O_2 and high CO_2 atmospheres were tested. First, tolerance to low O_2 partial pressures (1, 2, 3 or 21 kPa O_2 with balance N_2) was tested. Quality retention was improved as O_2 partial pressure was reduced and there was no induction of anaerobic respiration. Then, tolerance to high CO_2 partial pressures (0, 10, 15 or 20 kPa CO_2 plus 21 kPa O_2 and balance N_2) was tested. The high CO_2 partial pressures extended the shelf life of the shredded kale and no symptoms of CO_2 injury were detected. Finally, combinations of low O_2 and high CO_2 (1 or 2 kPa O_2 plus 15 or 20 kPa CO_2, with balance N_2, and an air control) were analysed. No differences were observed among the different gas combinations. An atmosphere of 1–2 kPa O_2 plus 15–20 kPa CO_2 and balance N_2 extends the shelf life of shredded Galega kale to 4–5 days at 20 °C, compared with 2–3 days in air storage. Predictive models of chlorophyll *a* and *b* degradation as a function of time and gas composition were developed.

Keywords: Quality; Shelf life; Respiration rate; Sensory attributes; Colour; Chlorophyll; Ascorbic acid; Fresh-cut

1. Introduction

Controlled and modified atmosphere (CA and MA) storage utilizing low O_2 and high CO_2 partial pressures are known to maintain quality and consequently extend shelf life of many fresh fruit and vegetables

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(Isenberg, 1979; Smock, 1979; Brecht, 1980; Kader, 1986; Ballantyne et al., 1988; Solomos and Kanellis, 1989; Zagory and Kader, 1989; Qi and Watada, 1997; Kader and Saltveit, 2002a). The decrease of the overall metabolic activity of plant tissues, including a decrease of respiration rate and inhibition of ethylene biosynthesis and action, are the main metabolic responses to reduced O_2 and elevated CO_2 atmospheres. The beneficial effects on product quality include: (i) delayed ripening and senescence, (ii) reduced incidence and severity of certain physiological disorders, (iii) reduced fungal growth, (iv) greater chlorophyll retention, (v) inhibited sprouting and flower opening, (vi) delayed fruit softening, (vii) delayed toughening in vegetables, (viii) reduced susceptibility to decay, and (ix) control of insect pests. Harmful effects may also occur if the partial pressures of O_2 and CO_2 are not within the range tolerated by the commodity. Exposure to O_2 partial pressures below the tolerance limit may result in anaerobiosis, tissue necrosis, and growth of anaerobic microorganisms (Kader et al., 1989). The latter may include species that constitute serious health hazards for humans if the produce is consumed (Brackett, 1994). Partial pressures of CO_2 higher than the tolerance limit may also induce anaerobiosis and tissue injury (Kader and Saltveit, 2002b).

Different fruit and vegetables have unique tolerance limits to low O_2 and high CO_2. The tolerance limits vary by commodity, cultivar, and physiological age, possibly due to differences in resistance to gas diffusion, as well as for different temperatures and times of exposure (Kader, 1989; Kader et al., 1989; Beaudry and Gran, 1993; Gran and Beaudry, 1993). Therefore, the ranges of O_2 and CO_2 partial pressures must be defined for each product and for each handling process applied (chopped, shredded or otherwise prepared).

Modified atmosphere packaging (MAP) is a commercial application of low O_2 and high CO_2 atmospheres. In order to design a successful MAP system, it is important to define the partial pressures of O_2 and CO_2 that prolong the shelf life of the fresh produce. No research has yet demonstrated a beneficial effect of reduced O_2 and elevated CO_2 on fresh shredded Galega kale (*Brassica oleracea* var. *acephala* DC.) quality. This is an important fresh-cut vegetable in the Portuguese market, which is still quite unexploited by the food industry, distributors, and retailers. The thinly shredded leaves are an ingredient in a traditional soup. The shredded Galega kale is commonly prepared at the retail level prior to display for sale; however, the shelf life at ambient store temperatures is very short, typically 1 day or less. Thus, development of MAP for shredded Galega kale could substantially improve the quality of the product that is available to consumers. Additionally, MAP could allow preparation of shredded Galega kale to be carried out at central distribution facilities, with associated reductions in the cost of processing.

The objectives of this work were: (i) to evaluate the tolerance to low O_2, (ii) to evaluate the tolerance to high CO_2, and (iii) to identify the best combination of O_2 and CO_2 partial pressures for preservation of shredded Galega kale in MAP.

2. Materials and methods

2.1. Plant material and handling treatment

Galega kale plants were grown at the Horticultural Research Unit of the University of Florida, Gainesville, Florida, USA. Galega kale is a nonheading leafy cole crop with long petioles and large midribbed leaves. Fully expanded leaves were picked early in the morning and transported immediately to the laboratory. Older, diseased, and injured leaves were discarded. Midribs were excised with a sharp knife, the leaves were then rinsed with potable water to remove dirt and insects, shredded in a hand shredder machine (1.5 mm wide slices), rinsed with chlorinated water (100 mg kg^{-1}; pH 7) for 30 s, and centrifuged in a salad spinner to remove adhering water. Approximately 150 g of shredded kale per replicate were placed in glass jars of 1.7 dm^3 capacity in a controlled temperature room. The jar lids had a rubber septum for gas sampling and two rubber tubes for gas application. A tube was extended from the inlet to the bottom of the jar to facilitate uniform flushing of the gas mixture. For each atmosphere treatment, a flowboard was connected to six jars in order to deliver a constant and equal gas flow rate. The gas flow rate to each jar was 1.7 ml s^{-1}. The flowboard was connected to a gas mixing board inside the room, which delivered the specified partial pressures of O_2, CO_2, and N_2. The error in the target partial pressure was 0.6 and 0.2 kPa for O_2 and CO_2, respectively. Gas streams were humidified by bubbling them through deionized