Available online at www.sciencedirect.com
SCIENCE DIRECT
Postharvest Biology and Technology 41 (2006) 181–190
Postharvest Biology and Technology
www.elsevier.com/locate/postharvbio

Metabolic activity and quality changes of whole and fresh-cut kohlrabi (*Brassica oleracea* L. *gongylodes* group) stored under controlled atmospheres

Víctor H. Escalona, Encarna Aguayo, Francisco Artés *

Postharvest and Refrigeration Group, Department of Food Engineering, Technical University of Cartagena, Paseo Alfonso XIII, 48, 30203 Cartagena, Murcia, Spain

Received 25 April 2005; accepted 2 April 2006

Abstract

The effect of different controlled atmospheres (CA) on the metabolic activity and the quality of kohlrabi stems and slices was studied. Gas compositions of 5 kPa O_2 + 5 kPa CO_2, 5 kPa O_2 + 15 kPa CO_2, and 21 kPa O_2 + 0 kPa CO_2 (as control) were applied. Kohlrabi stems were stored for 28 days at 5 °C with 95% RH in CA followed by 3 days at 15 °C and 60–70% RH in air. Sliced kohlrabi was stored under the same gas compositions for 14 days at 5 °C. For both whole and fresh-cut kohlrabi, the respiration rates, ethylene production, sugar and organic acid contents, and sensory attributes (appearance, taste, and texture) were evaluated. The respiratory activity of whole and fresh-cut kohlrabi was quite similar. For slices, ethylene production decreased throughout storage. In stems and slices, storage at 5 kPa O_2 + 5 or 15 kPa CO_2 slightly delayed the decline in sugars and organic acids. For whole and fresh-cut kohlrabi, 5 kPa O_2 + 15 kPa CO_2 was the most appropriate gas composition to assure good commercial quality.

Keywords: Minimal fresh processing; Respiration rate; Ethylene production; Sugar and organic acids content; Sensorial quality

1. Introduction

An increasing demand for kohlrabi from European Nordic countries has induced an expansion of the cultivated area in the Spanish Mediterranean coast. The harvest season for kohlrabi extends from November to March, requiring 50–65 days from seed to optimal maturity (Namesny, 1996) with a yield of about 35–45 t ha^{-1} (Maroto, 1995). Depending on the cultivar, kohlrabi may be white, purple, or green and it should be harvested when the stem is wider than 8 cm. However if it is harvested when smaller, the stems are young and tender and do not require peeling. Quality is enhanced by cool, humid weather, which prevents the edible portion from becoming tough and woody.

Weight loss, development of diseases, and increasing toughening are the most important causes of kohlrabi deterioration during cold storage (Namesny, 1996). The storage life of kohlrabi stored with leaves is only 2 weeks at 0 °C. Storage should be at or near 0 °C to prevent the development of diseases, mainly bacterial soft and black rot (Hardenburg et al., 1986). When stored without leaves, kohlrabi can be kept up to 3 months at 0 °C with 98–100% relative humidity (RH) to prevent shrivelling and toughening (Hardenburg et al., 1986). In CA conditions, a low O_2 level (1–5 kPa) generally reduces the respiration rate of fruit and vegetables. However, the effects of elevated CO_2 vary greatly between the species. Storage at low O_2 at an optimum temperature of −1 to 1 °C during 2 weeks resulted in a reduction of respiratory activity and enabled the control of potential pathogens in kohlrabi stems (Saray, 1994).

Processing vegetables to produce fresh-cut products generally increases their rate of deterioration. For best quality maintenance of fresh-cut vegetables concentrations of 1–8 kPa O_2 combined with 10 to 20 kPa CO_2 are recommended (Gorny, 1997; Artés, 2000). It is essential that all

* Corresponding author. Tel.: +34 968 325510; fax: +34 968 325433.
E-mail address: fr.artes@upct.es (F. Artés).

0925-5214/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.postharvbio.2006.04.001

fresh-cut items should be kept at a low temperature (0–5 °C) for keeping quality and extending shelf life (Huxsoll and Bolin, 1989; Varoquaux and Wiley, 1994; Ahvenainen, 1996; Artés, 2000). Controlled and modified atmospheres benefit fresh-cut products, mainly by reducing water loss, respiration rate and ethylene production, retarding microbial growth and decay, and inhibiting browning and some physiological disorders (Varoquaux and Wiley, 1994; Watada et al., 1996; Gorny, 1997; Artés, 2000). For fresh-cut vegetables, most of which fall into the low-acid category (pH 5.8–6.0), the high humidity and the extension of the cut surfaces can provide ideal conditions for the growth of microorganisms (Brackett, 1987).

Studies on postharvest behaviour of whole and fresh-cut kohlrabi are scarce. According to previous experiments (Artés et al., unpublished data), 5 kPa O_2 in combination with 5–15 kPa CO_2 might be a more appropriate gas composition to reduce the metabolic activity and microbial growth for kohlrabi stems and slices.

In general, the shelf life of the whole product compared to processed vegetables is two or three times longer because of the damage caused by cutting, which accelerates senescence (Huxsoll and Bolin, 1989; Varoquaux and Wiley, 1994; Ahvenainen, 1996; Artés, 2000). Because of the increased senescence in cut products this experiment used 28 and 14 days at 5 °C for stems and slices, respectively. In a retail situation stems are sold in non-refrigerated conditions, as opposed to fresh-cut kohlrabi, so an additional 3 days at 15 °C and 60–70% RH was used for stems.

The work described here sought to determine the effect of low O_2 combined with different CO_2 levels on the respiration rate, ethylene production, sugars and organic acids content, and sensory quality of whole and sliced kohlrabi. In addition, the work identified the major changes in quality attributes during transport, distribution and retail sale period of kohlrabi to European countries.

2. Materials and methods

2.1. Preparation of kohlrabi stems

'Kompliment F1′ kohlrabi (*Brassica oleracea* L. *gongylodes* group), a green cultivar, was field-grown in Torre Pacheco (latitude: 37°47′24″ and longitude 0°57′35″, Murcia, Spain) under a Mediterranean climate and harvested at the end of April. Stems were selected in the field and transported to the laboratory (40 km) where they were stored at 0 °C for 15 h. The next morning, kohlrabi stems were carefully inspected, selecting only those stems that were free from defects and with similar appearance. The average weight of plants was 740.0 ± 34.6 g (mean ± SE), with stem equatorial and longitudinal diameters of 12.1 ± 1.0 and 11.4 ± 0.6 cm, respectively. In a clean room at 7 °C, stems were washed in a water solution of 50 mg L^{-1} NaOCl for 1 min at 5 °C and pH 7.5. The stems were stored with leaves reaching a total length of 40–46 cm.

2.2. Processing of kohlrabi for fresh-cut

Those stems selected for fresh-cut were hand-peeled with a sharp knife to obtain a more uniform colour and tender product, and cut in slices of about 0.8 cm thickness using a commercial cutting machine (Hallde RG-100, Sweden). Slices were immersed in a 100 mg L^{-1} NaOCl water solution at 5 °C and pH 7.5 for 1 min and then drained. These operations were carried out in the same room used to select the stems.

2.3. CA conditions

Gas composition of 5 kPa O_2 + 5 kPa CO_2, 5 kPa O_2 + 15 kPa CO_2, 21 kPa O_2 + 0 kPa CO_2 (as control) were applied. These gas mixtures were selected following the recommendations of Saray (1994) and IIR (2000). To simulate real commercial practices, stems were stored for 28 days in CA at 5 °C followed by 3 days at 15 °C and 60–70% RH in air. Slices were stored for 14 days in CA at 5 °C.

2.4. Respiration rate and ethylene production measurements

Samples of three stems with leaves (2.1–2.2 kg) and 650–700 g for sliced kohlrabi were put into 2.6 and 1.5 L glass jars, respectively. For each gas mixture in the study, five jars were connected to a gas mixing panel (Flowboard, Davis, CA, USA) with a flow rate of 1–2 L h^{-1} humidified to 95% RH. The jars were closed and the initial head space composition (O_2, CO_2 and N_2) was measured using a 0.5 mL gas sample injected into a gas chromatograph (GC) (Shimadzu GC-14B, Tokyo, Japan) equipped with a thermal conductivity detector. The C_2H_4 production was measured with a GC (Hewlett Packard 5730A, Philadelphia, PA., USA) equipped with a flame ionisation detector on a 1 mL gas sample. The headspaces were analysed again after 2–4 h. The measurements were made periodically during storage at 5 °C. In between the measurements, the jars were flushed with the respective gas mixture.

2.5. Microbiological analysis

To determine microbial growth on kohlrabi slices, three random samples were taken on days 0 and 14. Three jars per treatment were analysed at each evaluation. A 30 g sample of kohlrabi was blended with 270 mL of sterile peptone buffered water (Merck Darmstadt, Germany) for 1 min in a sterile stomacher bag (Model 400 Bags 6141, London, UK) by using a Masticator (Seward Medical, London, UK). Serial dilutions were prepared in 9 mL PPS (Peptone Physiological Salt containing 8.5 g L^{-1} NaCl and 1 g L^{-1} bacteriological