Quality and Physiological Changes of Fresh-cut Kohlrabi

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Abstract. Fresh-cut diced (1 cm³) kohlrabi (*Brassica oleracea* L. Gongylodes Group) 'Kompliment F1' washed with chlorinated (100 mg·L⁻¹) water was stored in modified atmosphere packaging (MAP) up to 14 days at 0 °C. Samples were packed in 35- μ m oriented polypropylene (PP) bags or in plastic trays heat-sealed with unperforated or perforated (control) PP film. Changes in respiratory rate, ethylene emission rate, microbial growth, color, browning, decay, sugar contents, chemical attributes (soluble solids content, pH, and titratable acidity), and sensory attributes (visual appearance, aroma, flavor, and texture) were monitored. Cutting resulted in an increased CO₂ production compared to the whole stem, ranging from 2-fold immediately after cutting, to 8-fold at day 4. The equilibrium atmospheres within bags and trays were 6% O₂ plus 13% CO₂, and 13% O₂ plus 8% to 9% CO₂, respectively. In both MAP treatments, microbial development was delayed compared to air (control). The total aerobic counts were lower than 7.7 log CFU/g, which has been defined as a recommended limit criteria. No physiological disorders, decay, or off-flavor developed. Therefore, sensory quality attributes were suitable for commercial purposes. However, fresh-cut kohlrabi stored in MAP had slightly better color retention and microbial quality than the control.

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 to 65 d from seed to optimal maturity (Namesny, 1996), with a yield of $\approx$ 35 to 45 t·ha⁻¹ (Maroto, 1995). Depending on the cultivar, kohlrabi may be white, purple, or green and should be harvested when the stem is thinner than 8 cm so that 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. The edible portion can be eaten raw in salads or cooked in soup or stew.

Weight loss, development of diseases, and increasing toughening are the most important causes of kohlrabi deterioration during cold storage (Namesny, 1996). When kohlrabi is stored with leaves, it has a storage life of only 2 weeks at 0 °C. Storage should be at or near 0 °C to prevent the development of diseases, mainly bacterial soft rot and black rot. Stored without leaves, kohlrabi can be kept up to 3 months at 0 °C and 98% to 100% relative humidity (RH) to prevent shriveling and toughening (Harden-

burg et al., 1986). Perforated film packaging can be used to reduce moisture loss. Storage at low O₂ levels in controlled atmosphere (CA) 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 whole kohlrabi (Saray, 1994). CA of 3% O₂ plus 5% CO₂ reduced metabolic activity, extending storage life of kohlrabi without leaves up to 4 months at 0 °C (Moras and Champon cited by Namesny, 1996).

Demand for fresh-cut vegetables has developed rapidly in recent years in European markets, particularly for new products and institutional consumers. Fresh-cut vegetables are subject to stresses that make them very susceptible to physiological and microbial deterioration, which ends in the loss of quality, due mainly to enzymatic browning. For that reason shelf life of these products rarely exceeds 10 d, even under adequate packaging and chilling conditions (Ahvenainen, 1996; Artés, 2000; Brackett, 1987; Hamza et al., 1996). It is essential to keep the temperature as low as possible throughout the production and distribution chain, with 0 to 5 °C strongly recommended for better quality and longer shelf life (Ahvenainen, 1996; Artés, 2000; Francis et al., 1999). Shelf life of fresh-cut vegetables can be greatly extended by modified atmosphere packaging (MAP) through its effect on the reduction of respiration and ethylene production, which slows down senescence (Artés, 1996; Gorny, 1997; Huxsoll and Bolin, 1989; Kader et al., 1989; Shewfelt, 1987; Watada et al., 1990).

To the best of our knowledge, studies on fresh-cut kohlrabi have not been reported and, thus, it could be considered a new fresh-cut product. Therefore, the aim of the present

work was to study the physiological behavior of diced kohlrabi stems, characterized by the respiratory activity and ethylene emission, as well as the main quality attribute changes throughout 2 weeks of storage.

Materials and Methods

Preparation of kohlrabi stems. 'Kompliment F1' kohlrabi, a green cultivar, was field-grown in Torre Pacheco (Murcia, Spain) and harvested in the middle of November. Each plant was selected in the field, eliminating the soiled and decayed stems. Two hours maximum after harvesting they were transported to the laboratory and stored at 0 °C. The next day they were carefully inspected, selecting only those stems that were free from defects and with similar visual appearance. Plant weight ranged from 550 to 700 g, with stem equatorial and longitudinal diameters of 9.5 to 11 cm and 7 to 8.5 cm, respectively. Stems were washed in a water solution of 100 mg·L⁻¹ NaOCl at 5 °C (Ahvenainen, 1996).

Each stem was hand-peeled with a sharp knife to obtain a more uniform color and tender product and cut in dices of $\approx$ 1 cm³ using a commercial cutting machine (Hallde RG-100, Sweden). Dices were immersed into 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 a clean cold room at 7 °C.

Experiment I. Respiration rate and ethylene production

Rates of CO₂ (mg CO₂ kg⁻¹·h⁻¹) and C₂H₄ emission (μ L C₂H₄ kg⁻¹·h⁻¹) were determined by using a closed system (Kader, 1992). Four glass jars each containing three whole stems with leaves, and another four jars each containing 200 g of kohlrabi dices, were placed in a clean cold room at 0 °C for 14 d. The increase in CO₂ and C₂H₄ concentrations were monitored after closing the jars daily for 2 to 3 h. Then gas samples were taken with a plastic syringe from the headspace. In order to avoid CO₂ accumulation ($\leq$ 0.3%) and to maintain a high RH in the jars, a continuous air flow (3–4 L·h⁻¹ and 95% RH) with a gas mixing system (Flowboard, Davis, Calif.) was applied (Watada et al., 1996) between each measurement. Respiration rates were determined by using a 0.5-mL gas sample injected in a gas chromatograph (GC) (Shimadzu GC-14B, Tokyo) equipped with a thermal conductivity detector (TCD). The C₂H₄ emission was measured with a GC (Hewlett Packard 5730A, Palo Alto, Calif.) equipped with a flame ionization detector (FID) on a 1-mL gas sample.

Experiment II. Modified atmosphere packaging

Kohlrabi dices were placed into polypropylene trays of 17 × 11 × 4 cm (Plasal-Isap, Alcira, Valencia, Spain) or into bags (25 × 15 cm) containing 250 $\pm$ 5 g each one. Trays were covered with an antimist, oriented polypropylene (OPP) film of 35- μ m thickness and

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heat-sealed (Barket model Befor, France) on the edges. The film permeability at 23 °C and 75% RH was 5000–6000 mL·m⁻²·d⁻¹ per atmosphere for O₂ and 8000–12000 mL·m⁻²·d⁻¹ per atmosphere for CO₂ (data provided by the supplier Plásticos del Segura S.L., Murcia, Spain). Bags were made by using the same heat-sealed film (model IS/300H, Parker). Trays with perforated OPP (9 holes of 0.7-mm diameter on 187 cm²) were used as control (≤0.3% CO₂ and 21% O₂). To simulate real commercial practices, including the maximum shelf life and retail sale requirements, a storage period of 14 d at 0 °C was applied.

Gas measurements. Gas composition (O₂, CO₂, and N₂) within packages was monitored during storage by a GC (Perkin Elmer Autosystem, Norwalk, Conn.) equipped with a TCD. For analysis, 0.5-mL gas samples were taken from packages by using a plastic syringe through a silicone septum. The C₂H₄ levels were determined by injection of 1-mL gas samples in a GC (Hewlett Packard 5730A, Palo Alto, Calif.) equipped with a FID. Five repetitions were made for each treatment.

Microbiological analysis. Samples to determine microbial growth were taken on days 0 and 14 after processing. In both situations, three samples were used to obtain the mean value of each treatment. A 30-g sample of kohlrabi was blended with 270 mL of peptone water (Merck) for 1 min into a sterile stomacher bag (model 400 Bags 6041, Steward Laboratory, London) by using a Colwort Stomacher 400 (Steward Laboratory). Serial dilutions were prepared in peptone water. The following media and incubation conditions were used: plate count agar (PCA; Merck, Darmstadt, Germany) for mesophilic microflora, 48 h at 30 °C; and potato dextrose agar (PDA, Merck) for yeast and molds, 5 d at 30 °C. Duplicates were made for each dilution (Luna-Guzmán and Barrett, 2000). All microbial counts were reported as log colony forming units per gram of sample (CFU/g). Microbial quality was evaluated following the CNERNA-CNRS (1996) and Debevere (1996).

Color measurement. Browning on the kohlrabi dices and juice were measured with a tristimulus colorimeter (Minolta CR-300, Ramsey, N.J.), 8-mm diameter of viewing aperture, using a white plate as reference ($Y = 94.3$; $x = 0.3142$; $y = 0.3211$, standard CIE illuminant, 2° observer). Color was expressed as hue angle ($H^\circ = \tan^{-1} b^*/a^*$) and chroma [$(a^{*2} + b^{*2})^{1/2}$]. Measurements were done on the cut zone of the dices. The juice obtained from the product was placed in a glass tube to measure color after waiting 2 min for sedimentation of the pulp. This has been previously used to follow the extent of enzymatic browning in apple and pear juices (Sapers and Douglas, 1987), while L* was the parameter better related with enzymatic browning for lettuce (Castañer et al., 1999).

Chemical evaluation. Dices randomly taken from each sample were squeezed with a commercial turmix blender (Moulinex, Barcelona, Spain). The juice was analyzed for soluble solids content (SSC), pH, and titratable acidity (TA). SSC was measured with

a hand refractometer (Atago N1, Tokyo) and expressed as °Brix at 20 °C. The pH was determined by using a digital pH-meter (Crison 501, Barcelona, Spain). For titratable acidity (TA), 10 mL of juice was titrated with 0.1 N NaOH to an endpoint of pH 8.1 (AOAC, 1984) and expressed as grams of citric acid per liter.

Sugar content. Juice (20 mL) was frozen at -70 °C. At the end of the experiment, samples were thawed and centrifuged (1-13 model; Sigma, Germany) at 10,468 g_n for 10 min. The supernatant was filtered twice—the first time by using a Sep-Pack Cartridge (Waters, Ireland), and the second with a 0.45-μm nylon filter (Whatman, Clifton, N.J.). Sugar composition was determined by high-performance liquid chromatography (HPLC) equipped with a refractive index detector (L-7490 model; Hitachi, Tokyo) and a LiChrospher 250-4 NH₂ (5 μm) column (Merck). A 20-μL extract sample was injected using a mobile phase of 85 acetonitrile : 15 water (Merck, Germany) at a 1.5 mL·min⁻¹ flow.

Sensory evaluation. At the beginning and at the end of cold storage, an informal panel of five persons, familiar with sensory properties of kohlrabi, evaluated visual appearance, aroma, flavor, and texture. The evaluation was scored based on a nine-point scale (9 = excellent; 7 = good; 5 = acceptable, limit of marketability; 3 = poor; and 1 = extremely poor), adapted from Kader et al. (1973).

Weight loss, decay, and browning. Weight loss was measured in each replicate with a scale (Mettler PC 4400, Switzerland; accuracy of 0.1 g). Values were expressed as percentage of the initial fresh weight. Decay and browning were determined subjectively for each replicate using the scale (1 = none; 2 = slight; 3 = moderate; 4 = severe; and 5 = very severe) adapted from Martínez and Artés (1999). Dices scoring higher than 3 were considered as unacceptable for the consumer.

Statistical analysis. The experiment followed a completely randomized design (n

= 5) apart from microbial analysis (n = 3). Statgraphic Plus version 2.1 software was used for analysis of variance (ANOVA) and least significant difference (LSD) test at $P \leq 0.05$.

Results and Discussion

Experiment I. Respiration rate and ethylene emission

The respiration rate of diced and whole kohlrabi during cold storage decreased from 32 to 15 and from 16 to 2 mg CO₂ kg⁻¹·h⁻¹, respectively, with a faster decrease during the first 4 d of storage (Fig. 1). Cutting resulted in an increased CO₂ production than that for the whole stem, ranged from 2-fold immediately after cutting, to 8-fold at day 4. The observed trend agrees with reports for other fresh-cut produce where the rate increased 1.2- to 7-fold, depending on the produce, cutting size, and storage temperature (Ahvenainen, 1996; Artés, 2000; Cantwell, 1992; Varoquaux and Wiley, 1994).

There was little C₂H₄ production at 0 °C in whole and fresh-cut kohlrabi, and an emission rate lower than 0.05 μL C₂H₄ kg⁻¹·h⁻¹ was found. This behavior was not expected because C₂H₄ emission usually increases following minimal processing associated with the wound response (Ahvenainen, 1996; Artés, 2000; Cantwell, 1992; Varoquaux and Wiley, 1994). However, some studies have reported a slightly higher C₂H₄ emission in whole than in fresh-cut tomato at 2 °C (Artés et al., 1999), and slicing in pear did not increase C₂H₄ emission (Rosen and Kader, 1989).

Experiment II. Modified atmosphere packaging

Gas composition within packages. Steady state atmospheres within unperforated OPP packages of 6% O₂ plus 14% CO₂ for bags, and 13% O₂ plus 8% to 9% CO₂ for trays (Fig.

Fig. 1. Respiration rate of whole and fresh-cut kohlrabi for 14 d at 0 °C in air. Four replicates per treatment were used. Bars represent standard error (n = 4).

2) were obtained after 4 d. An air atmosphere was obtained in control packages. C_2H_4 levels were lower than 0.2 ppm in all treatments throughout the storage period.

Microbiological quality. At harvest total microbial count was lower than 1 log CFU/g, yeast count was 3.5 log CFU/g, and mold count was found to be lower than 2 log CFU/g. After 14 d of cold storage the TPC increased to 4.3 log CFU/g for the product stored in bags and 4.4 log CFU/g for that in trays. In control 6.2 log CFU/g was reached. Mesophilic bacteria counts in fresh-cut vegetables have been reported to be highly variable, ranging from 3 to 9 log CFU/g. For instance, counts on products analyzed soon after processing ranged from 3 to 6 log CFU/g, with shredded carrots being the most contaminated and cut iceberg lettuce the least (Nguyen-The and Carlin, 1994). In this experiment, as could be expected, by using moderately elevated CO_2 levels microbial growth was retarded (Table 1). The O_2 levels of 2% to 5% and CO_2 levels of 3% to 10% combined with refrigeration, have been shown not only to slow down product respiration, also to delay microbial growth, thus retarding physiological aging and extending shelf life (Francis et al., 1999). In fact, CO_2 , which is soluble in both water and lipid phases, has been reported to be the main factor responsible for the bacteriostatic effect on microorganisms in MAP (Church, 1994).

After cold storage yeast and mold counts were found to be lower than 2 log CFU/g. Results confirmed that yeasts are generally unaffected by MAP, but trend to decrease during storage, while the growth of molds, as aerobic microorganisms, are commonly delayed (Nguyen-The and Carlin, 1994). The TPC, yeast, and mold counts obtained after 14 d at 0 °C (Table 1) were always below the recommended limit (7.7 log CFU/g for microbial count, 5 log CFU/g for yeast, and 4 log CFU/g for mold) according to CNERNA-CNRS (1996) and Debevere (1996).

Color. The main factor that affected color changes was the extension of storage. However, the gas composition in MAP treatments had a slight effect on the final product color. After cold storage, decreases in L^* from 68 at harvest to 55 for control and to 62 for OPP-packed kohlrabi dices were found (Table 2). Additionally, an increase of hue angle values for all treatments, without significant differences among them, was found. Also, an increase of chroma values, particularly for the control and, to a lesser extent, for MAP was detected. After 14 d at 0 °C, MAP treatments delayed the unfavorable color change due to browning.

Fig. 2. Changes in O_2 and CO_2 in fresh-cut kohlrabi in modified atmosphere packaging (MAP) for 14 d at 0 °C. Five replicates per treatment were used. Bars represent standard error ($n = 3$).

Table 1. Total plate counts (TPC), yeast, and mold in fresh-cut kohlrabi at harvest and after 14 d of storage at 0 °C in modified atmosphere packaging (MAP). Mean values of three replicates are expressed as log CFU/g $\pm$ standard error.

Treatments	TPC	Yeast	Mold
At harvest	<1	3.5 $\pm$ 0.0	<2
After cold storage			
Control	6.2 $\pm$ 0.3	<2	<2
Bags (6% O_2 + 14% CO_2)	4.3 $\pm$ 0.2	<2	<2
Trays (13% O_2 + 8% to 9% CO_2)	4.4 $\pm$ 0.1	<2	<2

Particularly, a^* values remained significantly higher for kohlrabi in MAP than for the control, meaning better color retention (data not shown). This could be very probably related to low O_2 levels in MAP.

The L^* and hue angle of juice from stored kohlrabi dices did not change significantly for any treatment, although chroma was higher at the end of storage with a lower increase for MAP treatments (Table 2). Results indicated that in air storage a process of yellowing occurred. In contrast with results for dices, the juice color was not a parameter suitable for measuring enzymatic browning in fresh-cut kohlrabi. It could be probably due to the fact that the enzymatic browning was only a surface reaction.

Chemical attributes. After cold storage, significant decreases in SSC and AT values

were found for all treatments, compared to harvest, due probably to an increase in metabolic activity induced by the minimal processing. However, no changes in pH values after cold storage were detected (Table 3).

Sugar content. For kohlrabi, glucose and fructose were the predominant sugars, and their concentrations significantly decreased from 2 g/100 mL at harvest to 1.1–1.3 g/100 mL at the end of cold storage in all treatments. Our results agree with those previously reported by Souci et al. (1986). The glucose : fructose ratio was 1, and it remained stable during the storage period for all the treatments, suggesting a similar pathway of sugar metabolism independent of atmosphere composition and storage time. Picha (1987) also reported no change in that relation for cherry tomato fruit at different ripeness stages. At harvest, an overall glucose :

Table 2. Color of dices and juice of kohlrabi at harvest and after 14 d of storage at 0 °C in modified atmosphere packaging (MAP). Mean values $\pm$ standard error.

Treatments	Dices			Juice		
	L^*	Hue angle	Chroma	L^*	Hue angle	Chroma
At harvest	68.0 $\pm$ 2.2 a ^z	104.6 $\pm$ 0.6 b	7.1 $\pm$ 0.7 c	36.7 $\pm$ 0.7 a	121.6 $\pm$ 0.6 a	7.2 $\pm$ 0.3 c
After cold storage						
Control	55.2 $\pm$ 1.9 c	113.2 $\pm$ 0.9 a	14.4 $\pm$ 0.8 a	37.4 $\pm$ 1.0 a	119.5 $\pm$ 0.8 a	13.7 $\pm$ 0.5 a
Bags (6% O_2 + 14% CO_2)	61.9 $\pm$ 1.5 b	113.1 $\pm$ 0.8 a	11.3 $\pm$ 0.7 b	35.8 $\pm$ 1.0 a	120.0 $\pm$ 0.8 a	11.4 $\pm$ 0.5 b
Trays (13% O_2 + 8% to 9% CO_2)	61.9 $\pm$ 1.5 b	114.1 $\pm$ 0.8 a	12.9 $\pm$ 0.7 ab	35.9 $\pm$ 1.0 a	120.6 $\pm$ 0.8 a	11.3 $\pm$ 0.5 b

^zData within a column followed by the same letter are not significantly different ($P < 0.05$) according to LSD ($n = 5$).

Table 3. Soluble solids content (SSC), pH, and titratable acidity (TA) in fresh-cut kohlrabi at harvest and after 14 d of storage at 0 °C in modified atmosphere packaging (MAP). Mean values $\pm$ standard error.

Treatments	SSC	pH	TA
At harvest	7.6 $\pm$ 0.3 a ²	7.0 $\pm$ 0.0 b	0.62 $\pm$ 0.0 a
<u>After cold storage</u>			
Control	4.4 $\pm$ 0.3 b	6.9 $\pm$ 0.0 b	0.42 $\pm$ 0.0 b
Bags (6% O ₂ + 14% CO ₂)	4.2 $\pm$ 0.3 b	7.2 $\pm$ 0.0 a	0.31 $\pm$ 0.0 b
Trays (13% O ₂ + 8% to 9% CO ₂)	4.0 $\pm$ 0.3 b	7.0 $\pm$ 0.0 b	0.35 $\pm$ 0.0 b

²Data within a column followed by the same letter are not significantly different ($P < 0.05$) according to LSD (n = 5).

Table 4. Glucose, fructose, and sucrose contents, and glucose : fructose ratio in fresh-cut kohlrabi at harvest and after 14 d storage at 0 °C in modified atmosphere packaging (MAP). Mean values are expressed as g/100 mL juice $\pm$ standard error.

Treatments	Glucose	Fructose	Sucrose	Glucose : fructose ratio
At harvest	2.0 $\pm$ 0.1 a ²	2.0 $\pm$ 0.1 a	0.6 $\pm$ 0.0 a	1.0
<u>After cold storage</u>				
Control	1.3 $\pm$ 0.1 b	1.3 $\pm$ 0.1 b	0.1 $\pm$ 0.0 d	1.0
Bags (6% O ₂ + 14% CO ₂)	1.2 $\pm$ 0.1 b	1.1 $\pm$ 0.1 b	0.4 $\pm$ 0.0 b	0.9
Trays (13% O ₂ + 8% to 9% CO ₂)	1.2 $\pm$ 0.1 b	1.2 $\pm$ 0.1 b	0.2 $\pm$ 0.0 c	1.0

²Data within a column followed by the same letter are not significantly different ($P < 0.05$) according to LSD (n = 5).

Table 5. Visual appearance, aroma, flavor, texture, and browning of the cut surface in fresh-cut kohlrabi at harvest and after 14 d of storage at 0 °C in modified atmosphere packaging (MAP). Mean values $\pm$ standard error.

Treatments	Visual appearance	Aroma	Flavor	Texture	Browning of the cut surface
At harvest	8.0 $\pm$ 1.2 a ²	2.0 $\pm$ 0.7 b	9.0 $\pm$ 0.6 a	8.5 $\pm$ 0.8 a	1.0 $\pm$ 0.0 a
<u>After cold storage</u>					
Control	5.0 $\pm$ 0.9 b	7.5 $\pm$ 0.5 a	7.0 $\pm$ 0.4 b	6.3 $\pm$ 0.6 b	1.7 $\pm$ 0.2 a
Bags (6% O ₂ + 14% CO ₂)	6.1 $\pm$ 0.9 b	7.5 $\pm$ 0.5 a	6.8 $\pm$ 0.4 b	6.8 $\pm$ 0.6 ab	1.0 $\pm$ 0.1 a
Trays (13% O ₂ + 8% to 9% CO ₂)	6.0 $\pm$ 0.9 b	7.5 $\pm$ 0.5 a	7.0 $\pm$ 0.4 b	6.0 $\pm$ 0.6 b	1.2 $\pm$ 0.1 a

²Data within a column followed by the same letter are not significantly different ($P < 0.05$) according to LSD (n = 5).

fructose ratio of 0.7 in 12 blackberry cultivars was found while it was about 3 in apples and pears (Wrolstad et al., 1980). Sucrose was present in a low concentration at harvest (0.6 g/100 mL) and decreased more in control and tray treatments after cold storage (Table 4). This decrease could be related to a higher metabolic activity of control compared to MAP. Probably this sugar was the substrate used for the vegetable to maintain the glucose : fructose ratio. Consequently, in kohlrabi, changes in sucrose levels during cold storage could be a good indicator of senescence.

Sensory attributes. Compared to scores at harvest significant decreases were detected in visual appearance, aroma, and flavor at the end of cold storage (Table 5). However, the levels were still acceptable for commercial purposes. For fresh-cut lettuce, Hamza et al. (1996) reported that 10% or more CO₂ reduced enzymatic browning due to wounding and improved visual quality. An accumulation of aroma inside the packages could be responsible for the high score of this parameter after storage. All treatments induced a loss of flavor, probably due to the decreases in SST and TA. Changes in texture were similar between treatments, probably due to high RH that reduced water loss in dices. Consequently, use of MAP with moderate O₂ and CO₂ concentrations could be useful for maintaining sensory quality of fresh-cut kohlrabi.

Water loss, decay, and browning. Weight loss was lower than 0.1% at the end of cold

storage for all treatments. Neither physiological disorders nor decay were detected, although a slight browning on the cut surface for control was found, without differences among treatments (Table 5). The positive effect of MAP in avoiding weight loss and inhibiting oxidative reactions has been reported for a number of fresh-cut vegetables (Huxsoll and Bolin, 1989).

Conclusions

Whole and fresh-cut kohlrabi stored 14 d at 0 °C have a low to moderate nonclimacteric respiratory activity behavior and very low C₂H₄ production.

After 14 d at 0 °C, dices stored under all treatments have a quality higher than acceptable for commercial purposes, showing neither chilling or CO₂ injuries nor decay.

A modified atmosphere of 6% O₂ plus 14% CO₂ at 0 °C enhances chemical and sensory quality and decreases microbial count in comparison to control. This atmosphere also is able to inhibit browning on the surface of kohlrabi dices.

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