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Effect of cold storage and ozone treatment on physicochemical parameters, soluble sugars and organic acids in *Actinidia deliciosa*

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ABSTRACT

The production of kiwi fruits is a dynamic agricultural activity in Corsica (France). The fruits are either consumed directly or used to produce kiwi wine. They are often stored for 4–6 months in industrial freezer chambers at 0 °C or industrial ozone chambers. The aim of this study was to measure physical, chemical and fungicidal parameters, soluble sugars and non-volatile organic acids during storage in each of these types of chamber. Various standard and instrumental methods (physicochemical techniques, HPLC) in conjunction with statistical analysis were used. During storage, the kiwi mass, firmness and acidity decreased, whereas reducing sugar, °Brix and pH increased. There were statistical differences between the two chambers regarding reducing sugar and acidity. The ozone gas treatment had a fungicidal effect on *Botrytis cinerea*. The major soluble sugar present in the kiwi fruit was fructose, followed by glucose and sucrose. The concentrations of these sugars increased during storage in both air at 0 °C and ozone-enriched air. Organic acids are one of the important factors influencing fruit flavour. Citric and quinic acids predominated over malic, tartaric and ascorbic acids. During storage in the ozone chamber, concentrations of non-volatile organic acids decreased sharply after 25 weeks. Storage at 0 °C enabled better retention of organic acids.

1. Introduction

The kiwi fruit was introduced to the world market from New Zealand in 1950s. The export of fresh fruit led to rapid expansion and in 2006 kiwi fruit production in France was estimated at over 78,000 tons, representing 7% of worldwide production (FAO, 2005). In Corsica, kiwi fruit production is a dynamic agricultural activity and represents 10% of the French total (Eurostat, 2006). Kiwi fruit represent a source of antioxidant substances, which may intervene in the prevention of pathologies. Due to its composition, sensory characteristics and stability during preservation, the kiwi fruit has great potential for industrial exploitation (Cano Pilar, 1991; Soufleros et al., 2001).

The storage of fruit is very important for its quality, in particular its organoleptic flavour properties. The storage period for the fresh kiwi fruit market is about 4–6 months (Antunes & Sfakiotakis, 2002; Crisosto & Kader, 1999). During this storage period, rotting causes serious economic losses. *Botrytis cinerea* has been identified as the major fungal pathogen, causing soft rot decay during post-harvest storage (Lee, Lee, Park, Hur, & Koh, 2001). Different storage methods are used for the conservation of fruits and vegetables: air storage, controlled freezing-point storage at 0 °C, modified atmosphere packaging storage, controlled atmosphere storage (Antunes & Sfakiotakis, 2002; Das, Gürakan, & Bayındırlı, 2006), and ozone-enriched atmosphere storage (Tzotzakis, Borland, Singleton, & Barnes, 2007). Ozone can be a good alternative sanitizer for fresh fruits and vegetables (Han, Floros, Linton, Nielsen, & Nelson, 2002; Yousef, Kim, & Dave, 1999). It destroys micro-organisms by progressive oxidation of vital cellular components (Das et al., 2006).

Different storage methods have various effects on the quality of fruit. For example, Brix and reducing sugar increase during storage at 0 °C, while the firmness of the *Hayward* variety decreases (Manolopoulou & Papadopoulou, 1998). Brix is considered to be an important factor in terms of quality at the eating stage (Lallu, Searle, & MacRae, 1989; Tavarini, Degl'Innocenti, Remorini, Massai, & Guidi, 2008). Flesh firmness is reduced after cold storage and soluble solid contents increase significantly over 6 months at 0 °C (Tavarini et al., 2008).

Kiwi fruit flavour can be affected by a number of components, including sugars and organic acids. The flavour depends essentially on the balance between sugars and non-volatile organic acids. The most important kiwi fruit sugars are glucose, fructose and sucrose (Soufleros et al., 2001). Glucose and fructose concentrations increase gradually from the earliest stage of fruit development until harvesting. Organic acids are one of the important factors influencing fruit flavour (Chen, Liu, & Chen, 2009) and they accumulate at

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the early stages of fruit development (Zhao, Li, Jiang, Wang, & Yang, 2007). The most important organic acids contained in the kiwi fruit are citric, quinic and malic (Nishiyama, Fukuda, Shimohashi, & Oota, 2008).

In recent years, there has been increasing interest in the production of kiwi fruit due to its vitamin C content and high antioxidant capacity (Cassano, Figoli, Tagarelli, Sindona, & Drioli, 2006; Tavarini et al., 2008). The kiwi fruit is beneficial for certain health conditions (Cano Pilar, 1991; Carvalho & Lima, 2002; Tavarini et al., 2008). Kiwi fruit contains more ascorbic acid than citrus fruits (Nishiyama et al., 2004; Soufleros et al., 2001). Some authors (Adorisio, Cappelloni, Lintas, & Monastra, 1990; Das et al., 2006; Lombardi-Boccia, Cappelloni, & Lintas, 1986; Manolopoulou & Papadopoulou, 1998; Selman, 1983) have recorded significant reductions in vitamin C concentrations during cold storage. In particular, the vitamin C concentration of the Hayward variety changed from 200 to 37 mg/100 g fresh weight after 6 months of cold storage (Tavarini et al., 2008). No study has been carried out to investigate kiwi fruit quality as a result of ozone treatment storage. The objective of this work is to compare kiwi fruit quality as a result of two storage methods – air storage at 0 °C and ozone treatment – over a period of 7 months, in order to define the best storage method. We studied various parameters: physicochemical parameters (weight, firmness, pH, total acidity, reducing sugar, Brix), *B. cinerea* contamination, organic acids, soluble sugars and vitamin C.

2. Materials and methods

2.1. Plant material

Kiwi fruits (*Actinidia deliciosa* var. *Hayward*) were randomly collected on a plantation at Fiumorbu in Corsica (France). One hundred and fifty kiwi fruits were harvested on November 1st 2006. After sampling, the kiwi fruits were placed in an icebox and kept cool during transportation to the laboratory. At the laboratory, half the fruit was placed in a chamber at 0 °C and the other half in an ozone treatment storage chamber. Different analyses were performed over seven consecutive months, at 0, 7, 12, 15, 17, 18, 21, 23, 25, 27 and 29 weeks after the sampling date. At each date, 50 fruits were taken from each chamber. Ten replicates were performed for each analysis. The kiwi juice was extracted with a rotor machine and filtered, first by centrifugation, then through a Buchner funnel and finally through a 0.45 μm membrane.

2.2. Physicochemical and bacteriological parameters

Flesh firmness was measured using an Alpha-Brass penetrometer with an 8-mm diameter. °Brix was measured by an Abbe refractometer calibrated against sucrose. Reducing sugars were determined by the Boehringer Mannheim method. The pH was measured for the kiwi juice by pH metre. The total acidity was measured by neutralisation of 0.1 N NaOH in pH 8.1. The evaluation of *B. cinerea* was determined in kiwi juice by enzymatic dosage kit (control of the laccase activity). Results were compared with a reference index graded from 0 to 10.

2.3. Ozone treatment of kiwi fruits

Ozone gas was generated from a laboratory corona discharge ozone generator using oxygen, with a working voltage of 220 V, 50 Hz which is based on high frequency and water cooling principles (Opal, OG4 Model; Opal, Ankara, Turkey). Ozone gas treatment of kiwi was carried out in a chamber of 2 m^3. Gaseous ozone concentration was 4 mg/h in the chamber at a temperature of 0 °C and a humidity of 90–95%.

2.4. HPLC system analysis

A Perkin–Elmer 200 series system consisting of a binary pump (LC 200), an injector (20-μl injection loop) and a degasser (Series 200) was employed. For the sugar, the analyses were carried out using an Aminex HPX 87C (Bio-Rad, Marnes-la-Coquette, France) column (300 mm × 7.8 mm; particle size 9 μm) eluted with water (Milli-Q), flow rate of 0.6 ml/min. Elution was carried out isocratically for 20 min at 85 °C. Detection was carried out with a refractive index detector (LC 200). For the organic acids, the analyses were carried out using an Aminex HPX 87H (Bio-Rad, France) column (300 mm × 7.8 mm; particle size 9 μm) eluted with water/sulphuric acid (0.008 N) at a flow rate of 0.6 ml/min. Elution was carried out isocratically for 20 min at 35 °C. Detection was carried out at two wavelengths, 215 and 245 nm, using a diode array detector (DAD LC 200).

2.5. Chemicals and standard solution

Authentic standard compounds were purchased from Sigma–Aldrich (Chimie S.a.r.l., Lyon, France). For organic acids, ascorbic acid and sugars quantification, external standard calibration curves

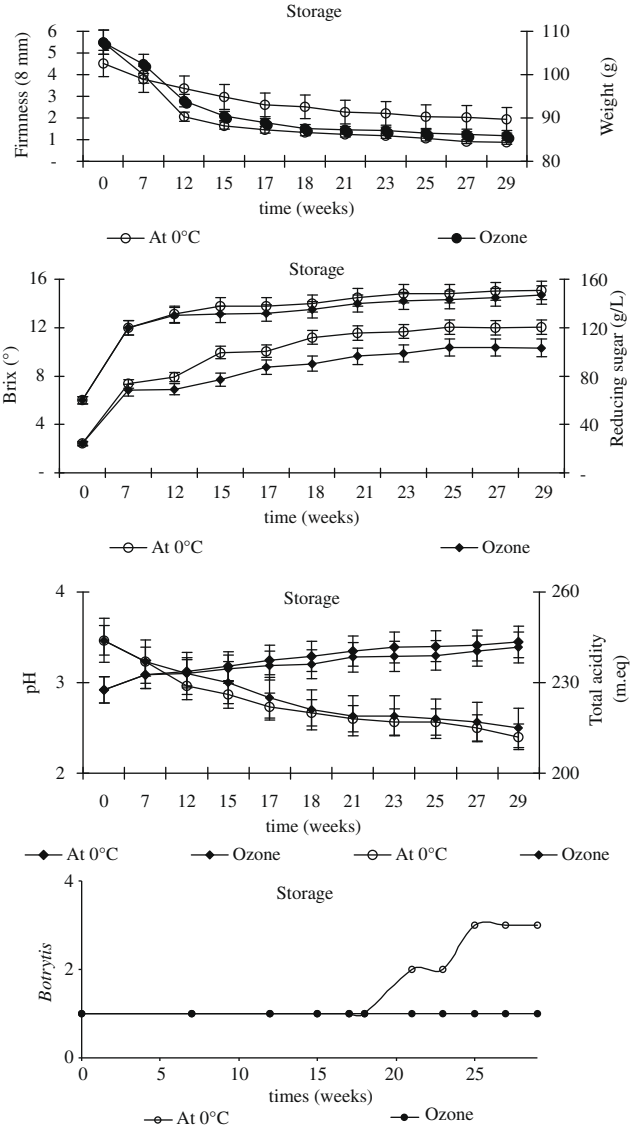

Fig. 1. Evolution of physicochemical parameters during storage.