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A study on quality loss of minimally processed grapes as affected by film packaging

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ABSTRACT

The influence of film barrier properties on the quality loss of minimally processed grapes stored at 5 °C was addressed. Table grapes (*Vitis vinifera* cv. Italia) differing in quantity and frequency of irrigation, were tested with five different packaging films. Two commercially available films were used: a multilayer film obtained by laminating nylon and a polyolefin layer (NP), an oriented polypropylene film (OPP), along with three biodegradable polyester-based films (NVT-100, NVT-50 and NVT-35). The packed grape quality during storage was determined by monitoring the headspace oxygen and carbon dioxide concentration, the grape sensory qualities, and the viable cell concentration of the following spoilage microorganisms: total viable bacterial count, lactic acid bacteria, yeasts and molds. All the investigated films successfully preserved the quality of packed produce for the entire observation period (35 d). However, the best results were obtained using high barrier films such as NP and NVT-100. Slight differences were recorded between the two sets of table grapes in terms of respiratory activity and sensory quality.

1. Introduction

Minimally processed fruit and vegetables include fresh, washed and chopped produce packaged in sealed polymeric films or trays. The market for fresh-cut products is increasing due to premium product quality, convenience and freshness (Vasconcellos, 2000; Rico et al., 2007).

The table grape is a non-climacteric fruit with problems during postharvest handling, storage and marketing. Grey mold, caused by *Botrytis cinerea*, is the principal cause of postharvest decay of table grapes both in the field and after harvest (Cappellini et al., 1986). Weight loss, colour changes and accelerated softening can also be an issue (Valero et al., 2006). Recently, many studies dealing with table grape preservation techniques have found that the use of ethanol, as a common food additive with antimicrobial activity, suppressed microbial growth and prevented berry decay (Lichter et al., 2002, 2003; Karabulut et al., 2004; Mlikota-Gabler et al., 2005; Lichter et al., 2005; Del Nobile et al., 2008).

There is growing pressure in the food-packaging field to replace petrochemical-based packaging material with environmentally friendly films (Tharanathan, 2003). Among the commercially available biodegradable packaging materials, films based on polysaccharides, in particular starch, currently have the most potential (Davis and Song, 2006). Bio-packaging still represents a niche market because of the cost of biodegradable films compared to traditional plastic materials. However, the polymeric matrices able to biodegrade into CO_2, water and biomass, or methane and biomass (Avella et al., 2005), could present a real contribution towards the reduction of environmental pollution. Sustained multidisciplinary research efforts are needed for a successful implementation and commercialization of eco-friendly packaging materials.

In earlier work, Del Nobile et al. (2008) investigated the influence of postharvest treatments (ethanol, chlorinated water and hot water) on the quality loss kinetics of freshly processed grapes packaged in biodegradable films. Results suggested that ethanol was the best solution to preserve the microbial stability of the fresh produce without affecting its respiration rate to any great extent. Based on these results, the influence of film permeability on the quality loss of grapes has been addressed in this work. In particular, clusters of table grapes (*Vitis vinifera* cv. Italia) grown under two irrigation water volumes, were treated in ethanol solution prior to packaging

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in different bags made of two types of commercially available films and in three biodegradable polyester-based films. This was done in order to determine the role of the barrier properties of the selected packaging materials in influencing the loss of grape quality during storage.

2. Materials and methods

2.1. Raw materials

Grapes were harvested on a farm located in a wine-growing area southeast of Bari (Casamassima) from a vineyard installed in 2002 with "140 Ru" (*Vitis berlandieri x Vitis rupestris* du Lot) rootstock, which was grafted with *V. vinifera L.* cv. Italia b. in 2003. The vineyard has a row spacing of 2.5 m × 2.5 m (with 1600 plants/ha) with the "Apulia tendone" training system and is covered with net to protect against hail. It is managed according to the typical cultivation technique of the zone. The vineyard is irrigated with local water, supplied by pipes (two per plant). In order to appraise the effects induced by the various irrigation volumes, two different treatments were studied. Each treatment was realized by delimiting 95 vines (5 rows per 19 vines). For each treatment, 45 plot replications (3 rows per 15 vines) placed along three central rows were designed. The supply of the two different irrigation volumes, considered constant for the duration of the interventions (24 h) and the turns (9 d), was obtained using pipes with different hourly outputs. For this, pipes able to supply an hourly output equal to 8 or 16 L/vine were used. As a consequence, the seasonal irrigation volumes obtained were 2500 and 5000 $m^3\ ha^{-1}$, respectively. Grapes obtained from the two different irrigation volumes will be referred to as A and B, respectively.

2.2. Sample preparation

After harvest, the grapes were transported to the laboratory and selected to obtain homogeneous batches based on colour, size, lack of damage, health and greenish rachises. After selection, the samples were washed with tap water to remove residues and dipped in a solution of ethanol (50%) for 5 min to control microbial spoilage. After dipping, 100 g of each grape sample were packed using different packaging materials: two biodegradable monolayer films (NVT-100, thickness 100 μm, NVT-50, thickness 50 μm) and one multilayer polyester-based co-extruded film (NVT-35 thickness 35 μm), kindly provided by Novamont (Novara, Italy); an Oriented Polypropylene film (OPP, thickness 20 μm), kindly provided by Metalvuoto (Milano, Italy); a multilayer film obtained by laminating a nylon layer with a polyolefin-based film (NP, thickness 95 μm) (Cianfano, Italy); and a multilayer material obtained by an aluminium-based layer co-laminated with a polyethylene film (All-PE, thickness 133 μm), kindly provided by Goglio (Daverio, Varese, Italy). The filled bags, having a surface area of about 500 cm^2, were hermetically sealed and stored at 5 °C for more than 1 month.

The package headspace volume was determined by the difference between the total volume of the packages and the volume of the sample. The total volume was measured by dipping the packages containing the fruit into a graduated water container and by observing the increase in the water level. Similarly, the volume of the samples was calculated by immersion of the clusters in a graduated cylinder with water, and by measuring the increase in water level.

2.3. Headspace gas composition

O_2 and CO_2 contents of the packaged grapes were measured using an O_2 and CO_2 meter (PBI Dansensor, Checkmate 9900, Rønnedevej 18, DK-4100 Ringsted, Denmark). The volume taken from the package headspace for gas analysis was about 10 cm^3. To avoid modifications in the headspace gas composition, due to gas sampling, each package was used only for a single determination of the headspace gas composition.

2.4. Microbiological analyses

Microbiological analyses were performed during storage. For each sample, 25 g of grapes (five berries) were detached from different clusters, immersed in 225 mL of sterile distilled water and shaken for 30 min at 200 rpm on a rotary shaker. The wash was serially diluted and two aliquots of each dilution were spread over appropriate media in Petri dishes. The media, all from Oxoid (Milan, Italy), and conditions were as follows: Plate Count Agar (PCA), modified by adding 0.17 g L^{-1} of cycloheximide (Sigma–Aldrich, Milan, Italy) after autoclaving, incubated at 32 °C for 48 h, for total bacterial count; Sabouraud dextrose agar, supplemented with chloramphenicol (0.1 g L^{-1}) (C. Erba, Milan, Italy), incubated at 25 °C for 48 h, for yeasts; deMan Rogosa Sharpe agar (MRS), modified by adding 0.17 g L^{-1} of cycloheximide after autoclaving, incubated at 30 °C for 4 d under anaerobiosis, for lactic acid bacteria; Potato Dextrose Agar (PDA), supplemented with chloramphenicol (0.1 g L^{-1}), incubated at 20 °C for 7–10 d, for moulds.

2.5. Product appearance

A panel of seven judges carried out the sensory analysis of the table grape samples to discriminate the sensory characteristics (odour, colour, firmness and general visual quality). Freshly cut products from the batch were used as controls. The intensity of the attributes evaluated was quantified on a scale from 1 to 5, where 1–2 = very poor, 3–4 = fair, and 5 = excellent, according to the procedure reported by Giménez et al. (2003). Scores below 3 for any of the attributes assessed were considered as an indicator of the end of the acceptable visual quality.

2.6. Statistical analysis

To determine whether significant differences ($p < 0.05$) existed among the values of the fitting parameters, the one-way analysis of variance (ANOVA) and Duncan's multiple range test, with the option of homogeneous groups, were used by means of STATISTICA 7.1 for Windows (StatSoft, Inc, Tulsa, OK, USA).

3. Modelling

In previous papers, Del Nobile et al. (2006, 2007, 2008) presented a mathematical model that predicts the respiration rate of minimally processed produce. The above-mentioned model is based on a simplified version of the Michaelis–Menten equation:

$$r_{O_2} = A_1 \cdot \exp\{-A_2 \cdot [CO_2]\} \cdot [O_2] \quad (1)$$

where: r_{O_2} is oxygen consumption rate expressed as [mL/kg h], $[O_2]$ is the percentage oxygen concentration, $[CO_2]$ is the percentage carbon dioxide concentration, A_1 is the pre-exponential term expressed as [mL/kg h], and is the maximum oxygen consumption rate, A_2 is the exponential factor and accounts for the carbon dioxide induced respiration inhibition, which is dimensionless. Del Nobile et al. (2006, 2007, 2008) also assumed that the ratio between carbon dioxide produced and oxygen consumed (respiratory quotient, RQ) is constant, but not necessarily equal to one:

$$r_{CO_2} = K_1 \cdot \{A_1 \cdot \exp\{-A_2 \cdot [CO_2]\} \cdot [O_2]\} \quad (2)$$