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Changes in the quality and antioxidant components of minimally processed table grapes during storage

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ABSTRACT

Minimally processed table grapes have traditionally been used as a component of fruit salads; only recently has been taken into account the possibility of producing single-portion packages in small containers. The aim of this research was to assess the shelf-life of small table grape clusters, including some of the most utilized varieties in Italy, such as 'Vittoria', 'Superior seedless®', 'Italia', 'Crimson seedless', 'Red Globe' and 'Black Pearl', packed in polyethylene containers. Chemometric techniques including principal component analysis (PCA) and linear discriminant analysis (LDA) were carried out on six parameters to develop discriminant models. The berry firmness remained satisfactory until the 15th day of storage, especially in seedless cultivars such as 'Superior seedless®' and 'Crimson seedless'. Variations of weight loss and colour were almost absent in all cultivars. A significant increase in CO_2 and a decrease in O_2 inside the packages were observed during the second week of storage. During the cold storage period, most of the quality parameters remained stable in all cultivars. LDA achieved satisfactory discrimination of grape fruits according to the variety and the storage time. The results indicated the possibility of packaging small clusters of table grapes that could maintain good quality parameters for a rather long storage period without excessive reduction of the antioxidant activity of the product.

1. Introduction

Grapes are one of the most diffuse fruits in the world both as fresh fruit (table grape) and when processed into wine, grape juice and raisins. Italy is ranked sixth (over 1.0 Mt) in the world context of table grape production and the first in Europe (OIV 2014). In the national context, Sicily produces 21% of table grapes (0.22 Mt) (ISTAT 2010).

As fresh fruit, grapes are very delicate with very high loss at harvest and during distribution. Packaged minimally processed grapes are emerging as a convenient ready-to-eat snack. The two most used protection technologies for minimally processed vegetables are low temperature and controlled (CA) or modified (MA) atmospheres. Several studies have shown that low levels of O_2 in combination with high levels of CO_2 can reduce respiration rates, control microbiological growth and prolong shelf-life of the product (Day B.P.F., 1993; Watada et al., 1996; Jacxens et al., 2003; Allende et al., 2004).

Commercially packaged table grapes, stored in clusters in perforated packaging, have a short shelf-life, typically 8–10 weeks, as a result of their exposure to the environment, although shelf-life varies greatly with storage conditions and grape variety and can range from 2 weeks to 6 months (Franke, 2006).

The shelf-life of these grapes is often shortened by weight loss, stem browning, softening, shattering and decay (Crisosto et al., 2001; Perkins-Veazie et al., 1992; Del Nobile et al., 2008; Del Nobile et al., 2009). As reported by Alberio et al. (2015), minimally processed grapes represent a favourable alternative to currently available snacks for automatic vending machines commonly used by various communities.

Table grapes are a non-climateric fruits that show severe problems during postharvest management, storage and marketing. As with other fruits, weight loss, colour changes and accelerated softening affect product quality (Valero et al., 2006). Additionally, the deterioration of postharvest quality in table grapes is also attributed to rachis browning and a high incidence of berry decay (Carvajal-Millàn et al., 2001; Crisosto et al., 2002). Some of the quality traits of table grapes, such as berry size and skin thickness, can represent limiting factors when preparing minimally processed products. The physical damage incurred during minimal processing, especially the presence of cut surface, causes destruction of the cellular membrane, putting enzymes and their substrates in direct contact, which accelerates the loss of quality. Microbial attacks can easily be found in badly dried and damaged grapes.

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The storage life is shorter with higher initial microbial loads (Bolin et al., 1977). The present bacterial population during low-temperature storage mainly consists of species belonging to the *Pseudomonadaceae* and *Enterobacteriaceae* (Lund, 1992; Nguyen-the and Carlin, 1994). Minimally processed grapes may be subject to risk of contamination with human pathogens, and other possibilities of contamination are represented by the irrigation water, seeds, soil, processing and packaging (Ragaert et al., 2007).

The aim of this research, which was carried out in 2014 and 2016, was to assess the shelf-life of small size table grape clusters of the most diffused varieties in Italy packed in polyethylene containers and sealed using polyamide-polyethylene films. In addition, quality attributes, total phenolic content, vitamin C and antioxidant activity were evaluated during cold storage.

2. Materials and methods

2.1. Chemicals

2,6-dichloroindophenol, Folin-Ciocalteu reagent, fluorescein, 2,2′-azobis (2-amidinopropane) dihydrochloride (AAPH), and 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox) were purchased from Sigma Chemical Co. (St. Louis, MO).

All other chemicals were of analytical grade, and the solvents used for chromatography were HPLC grade (Merck KGaA, Darmstadt, Germany).

2.2. Samples and experimental procedure

The table grapes used included three red cultivars, namely, 'Red Globe', 'Crimson seedless', 'Black Pearl', and three white cultivars, namely, 'Vittoria', 'Superior seedless®' and 'Italia'. The clusters were harvested from 10- to 12-years old commercial vineyards located in the Sicilian protected Geographical Identification (PGI) area of Mazzarrone, Catania (37°44′ N, 15°11′ E, 130 m a.s.l.) in the years 2014–2016. All varieties were grafted onto 140 Ru. rootstocks (*V. berlandieri* × *V. rupestris*). The vines were spaced at intervals of 2.50 m × 2.50 m and trained to a "tendone" training system covered with white net at a height of 2.5 m. The orchard received ordinary horticultural care in terms of soil management, fertilization and irrigation in accordance with standard commercial practice in the area. At optimum commercially ripe stage (15.0°Brix), 20 kg of each cultivar was harvested.

2.3. Sample preparation

Harvested clusters of the six varieties were immediately transported to the laboratory, where the main morphological values were measured. The clusters were selected to obtain homogeneous batches in terms of colour, uniform size, firmness, absence of injuries and healthy greenish rachises. The clusters were washed in a chlorine (5–20 ppm) and citric acid (80 ppm) solution and dried by laminar flow. Morphological parameters (berry weight, diameter and volume) were recorded. Each bunch was then cut with sanitized scissors to obtain small clusters of approximately 30–50 g.

The small clusters were packaged in 10 × 10 cm rigid polyethylene containers sealed using polyamide-polyethylene film (Niederwieser, Bolzano). A total of 90 sealed boxes (15 packages for each grape variety)were stored at 4 °C with 90% RH and evaluated for quality after storage on days 0,7 and 14. For each sampling date, five trays for each grape variety were used for the physicochemical analysis. The gas composition (O_2 and CO_2 percentages during the storage period was determined by Dansensor PBI (Ringsted, Denmark).

2.4. Physicochemical analysis

Berry physicochemical analysis included firmness, colour, weight loss, total soluble solids content (TSS), titratable acidity (TA) and fructose, glucose and vitamin C contents.

Berry firmness was determined using a TX-XT2i Texture analyser (Stable Microsystems, Godalming, U.K.). Colorwas evaluated using a Minolta colorimeter CR410 (Minolta Camera Co., Osaka, Japan). Color was expressed as L*, a* and b* for all samples and also as hue angle for red and black cultivars. The weight of each tray was recorded on the packaging day and after the different sampling dates. Weight losses were expressed as a percentage of the original weight. Total soluble solids content (TSS) was determined in the juice obtained from 10 berries for each tray with a digital refractometer. Titratable acidity (TA) was determined in juice by potentiometric titration with 0.1 N NaOH up to pH 8.1 and expressed as g of tartaric acid equivalent per 100 mL^{-1}.

Fructose and glucose were analysed using a Waters 600E HPLC system. Centrifuged grape juice (5 mL) was passed through a Sepak-C18 cartridge, and 1 mL of cleaned juice was diluted to 50 mL with double-distilled water. Sugars were detected using a Waters 410 Differential Refractometer detector with a reference cell maintained at 35 °C. A Luna 5 µ NH_2 column (250 × 4.6 mm) was used. The column was maintained at 30 °C with a waters thermostated column compartment. Samples were eluted with an acetonitrile-water (80-20) solution and the flow rate was 1.8 mL min^{-1}

Vitamin C was determined by titration with DIF (2,6-dichloroindophenol sodium salt hydrate) using the official method described by the AOC (AOAC, 1990).

2.5. Antioxidant activity

2.5.1. Oxygen radical absorbance capacity (ORAC) assay

The antioxidant activity was determined using the ORAC assay described by Cao et al. (1993) and improved by Ou et al. (2001) with some modifications. Briefly, the measurements were carried out on a Wallac 1420 Victor III 96-well plate reader with a fluorescence filter (excitation 485 nm, emission 535 nm). Fluorescein (116 nM) was the target molecule for free radical attack, and AAPH (153 mM) was used as the peroxyl radical generator. The reaction was conducted at 37 °C and pH 7.0. All solutions were freshly prepared prior to analysis. All samples were diluted with phosphate buffer (1:25–100, v/v) prior to analysis, and the results were reported as micromoles of Trolox equivalents per 100 g of fresh weight.

2.5.2. FolinCiocalteu reagent (FCR) assay

The total phenolic concentration of fruit, expressed as mg of gallic acid equivalent (GAE) 100 g^{-1} of berry, was measured using the Folin-Ciocalteu reagent assay (Singleton et al., 1999). Grape berries (50 g) were ground in liquid N_2 and recovered into a 100-mL flask with water-methanol (2:8) containing 2 mmol L^{-1} sodium fluoride to inactivate polyphenol oxidases. After centrifugation, the supernatant was analysed for total phenolic content. Diluted samples (1 mL) were mixed with 5 mL of FCR commercial reagent (previously diluted with water 1:10 v/v) and 4 mL of a 7.5% sodium carbonate solution. The mixture was stirred for 2 h at room temperature while avoiding strong light exposure. The absorbance of the resulting blue solution was measured spectrophotometrically at 740 nm, and the concentration of total phenols was expressed as (±) gallic acid equivalents (mg L^{-1}).

2.6. Statistical and multivariate analysis

Analysis performed by STATSOFT 6.0 was used to test the significance of each variable ($p < 0.01$) during storage, and separation of the means was executed using a Tukey post-hoc test. Multivariate data analyses were applied to the autoscaled data matrix.

Principal component analysis (PCA) was used to display the samples