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Cultivation under salt stress conditions influences postharvest quality and glucosinolates content of fresh-cut cauliflower

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ABSTRACT

Quality and chemical composition of two fresh-cut cauliflower cultivars (the white type 'Flamenco' and the green type 'Monteverde'), grown in a soilless system with two electrical conductivities of the nutrient solutions (2.0 and 4.0 dS m^{-1}), were investigated in order to evaluate the effect of salinity on product characteristics and shelf-life during cold storage (14 d at 4 °C). Preharvest salinity of 4.0 dS m^{-1} increased the floret's dry matter and soluble solids content in both genotypes and improved their colour retention during storage. The postharvest CO_2 production was higher in salt-stressed florets compared to control, but after 7 d of storage control florets showed an acceleration in respiratory metabolism, indicating an intensification of senescence processes. Preharvest salt stress increased the concentration of glucosinolates in a genotype-dependent way, improving also the concentration of total polyphenols and ascorbic acid, hence the antioxidant activity of florets. The time-course of secondary metabolites during storage indicated complex interactions among genotype, preharvest growing conditions and different classes of compounds, whose understanding could help in tailoring specific breeding programmes aimed at improving the postharvest nutraceutical profile of the product. Overall, these results demonstrate that the application of a controlled salt stress, through the use of a soilless system, improves fresh-cut cauliflower characteristics, enhancing also the shelf-life of the product.

1. Introduction

The market of fresh-cut fruit and vegetables is increasing in recent years as a result of changes in consumer needs that demand fresh, healthy and convenient foods (Rico et al., 2007). Fresh-cuts generally are more perishable than intact products because they have been subjected to physical operations (e.g., peeling, slicing), leading physiological stresses and biochemical deterioration (Watada et al., 1996), which may result in degradation in quality characteristics and loss of freshness (Rico et al., 2007). Moreover, significant loss of nutritional and functional properties has been shown to occur in postharvest (Brecht et al., 2004).

There is plenty of information on the effects of postharvest treatments and conditions (e.g. temperature, modified atmosphere packaging) on the shelf-life of fresh-cut products (e.g. Rico et al., 2007). However, there is little information concerning the influence of biological and technical factors during cultivation (preharvest conditions) on the quality maintenance of fresh-cut products during storage. It is well known that salinity stress improves some quality characteristics of several vegetables (Leonardi et al., 2004; Rouphael et al., 2012), stimulating also the biosynthesis of bioactive compounds (Giuffrida et al., 2014; Oh et al., 2009). It has been reported that salt stress can have a positive effect on lettuce processability, shelf-life (Scuderi et al., 2011) and consumer acceptability (Clarkson et al., 2005). Therefore, controlled stresses could be used to improve quality of the raw material that has to be excellent to maintain quality of the transformed product (Watada et al., 1996).

Cauliflower (*Brassica oleracea* L. var. *botrytis* L.) is an important vegetable belonging to the Brassicaceae family and widely diffused in the Mediterranean countries. Epidemiological studies show that a diet rich in *Brassica* vegetables can reduce the risk of cancer incidence (e.g. Neuhouser et al., 2003). These vegetables are rich in glucosinolates, a class of secondary metabolites in plants having, together their hydrolysed products, anticarcinogenic properties (Holst and Williamson, 2004). To meet the consumer's requirement for vegetables ready to use and healthy, cauliflower florets are commonly available.

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Cauliflower heads differ in their respiration rate and shelf-life period to their corresponding florets, that have a high respiration rate (0.02–0.04 g kg^{-1} h^{-1} CO_2 at 5 °C) and perishability (Kader, 2002; Saltveit, 1997). Studies to extend the shelf-life and to reduce loss of nutritional and functional compounds during postharvest of fresh-cut cauliflower refer mainly to the use of controlled and modified atmosphere packaging (Schreiner et al., 2006).

Moderate salt stress (4 dS m^{-1}) increases osmotic pressure of the cauliflower tissue, improves dry matter, titratable acidity, and soluble solids in the heads (Giuffrida et al., 2013), whereas the effects on glucosinolates (GLS) content depend on GLS group (Giuffrida et al., 2017). High health-promoting effects are attributed to the catabolic products derived from aliphatic and indolic GLS. However, indolic and alkenyl GLS, but not alkyl GLS, have been associated with bitter flavour that may alter taste in cauliflower, influencing consumer acceptance (Schonhof et al., 2004). Besides, the content of GLS groups changes among cauliflower genotypes (Bhandari and Kwak, 2015; Kushad et al., 1999).

The aim of this experiment was to study whether the irrigation with saline water during the cultivation may influence postharvest quality and GLS content of two cauliflower cultivars for fresh-cut consumption.

2. Materials and methods

2.1. Experimental site

The experiment was carried out from February to April at the Experimental Farm of University of Catania, Italy (37.31 °N, 15.40 °E, 20 m a.s.l.), in a 800 m^2 protective shelter to prevent the interaction with rainfall water. The local climate is semi-arid Mediterranean (*Cs* climate according to Köppen classification), with mild, wet winters and warm, dry summers. During the experiment, the microclimate conditions inside the shelter were constantly monitored and recorded on a data logger (CR10X; Campbell Scientific Ltd, Loughborough, UK). The minimum, mean, and maximum air temperature were 10.8, 17.2 and 22.1 °C, respectively. The minimum, mean, and maximum vapour pressure deficit (VPD) were 0.26, 1.02 and 1.56 kPa, respectively. The minimum, mean, and maximum global radiation were 1.26, 7.95 and 13.55 MJ m^{-2}, respectively.

2.2. Plant material, experimental treatments and growth conditions

Cauliflower seedlings (*B. oleracea* L. var. *botrytis* L.) cv. 'Monteverde' F_1 (Enza Zaden, Enkhuizen, The Netherlands) – green type - and cv. 'Flamenco' F_1 (Bejo, Oceano, California) – white type - were transplanted on 2 February at the two-true-leaf stage into 5 L volume pots (20 cm height, 19 cm width) using sand as growing medium. The plant density was 2 plants m^{-2} (50 cm between pots and 100 cm between troughs). The experimental treatments consisted of two nutrient solutions (NS): a control NS (2 dS m^{-1}) and a saline NS (4 dS m^{-1}) obtained by adding 20 mmo L^{-1} of NaCl to control NS.

The control NS had the following composition (mmol L^{-1}): 11.0 NO_3^-, 1.3 $H_2PO_4^-$, 6.6 K^+, 0.9 SO_4^{2-}, 3.4 Ca^{2+}, 2.5 Mg^{2+}, 0.5 NH_4^+, 2.1 Na^+, 1.8 Cl^-. The concentration of microelements (μmol L^{-1}) was: 15 Fe^{3+}, 10 Mn^{2+}, 0.75 Cu^{2+}, 5 Zn^{2+}, 30 B^{3+}, 0.5 Mo^{6+}. The pH was 6.0. The use of saline NS started 5 d after transplanting, and the final EC of the saline NS (4 dS m^{-1}) was gradually achieved by adding 10 mmol L^{-1} of NaCl for the first two days and reaching the final NaCl concentration (20 mmol L^{-1}) afterwards. The two nutrient solutions were pumped from independent tanks and supplied using a drip irrigation system with one emitter per plant (4 L h^{-1}). The irrigation volume and frequency were determined according to the water retention curve of the sand, the VPD inside the greenhouse and the plant growth. The amount of nutrient solution supplied at each irrigation was quantified every then days according to the volume of substrate exploited by the roots and the corresponding water contained in the substrate at intervals of −10 hPa to −50 hPa of matric potential (12 mL 100 mL^{-1}). Additionally, the volume of irrigation water was adjusted to ensure a leaching fraction of at least 75% to maintain EC value at the root level close to the EC of the nutrient solutions applied. For the irrigation frequency, the integral of VPD referred to the period during which plants consumed (measured gravimetrically in some plants per each treatment) the volume of water determined above (water contained in the substrate at intervals of −10 hPa to −50 hPa of matric potential) was quantified. This VPD value was considered as threshold for irrigation during the successive then days, until the next measurement. The experiment ended with the final harvest (head maturity) on 12 April in the white type-control, 15 April in the white type-4 dS m^{-1}, 20 April in the green type-control, and 27 April in the green type-4 dS m^{-1}.

2.3. Cauliflower processing

After harvest, cauliflower heads were immediately transported to the laboratory, divided in single florets, dipped for 10 min into a sodium hypochlorite solution (0.10 g L^{-1}), rinsed in tap water and blotted dried. The product was placed in polyethylene terephtalate (PET) plastic trays (approximately 400 g per tray), packaged with a double barrier of 25 μm anti-fog plastic film, with oxygen permeance at 23 °C below 0.08 mmol m^{-2} 24 h^{-1} and stored at 4 °C for 14 d.

Three plastic trays for each treatment (2 NS x 2 cultivars) and day of storage (0, 7 and 14 d) were filled randomly with raw material obtained by three cultivation replicates.

2.4. O_2 and CO_2 concentrations and qualitative traits

Before packaging, length and diameter (mean of two orthogonal measurements) of florets were measured. At the beginning and after 7 and 14 d of storage at 4 °C, the O_2 and CO_2 concentrations in the packages were measured using the gas analysis equipment CheckPoint, Dansensor (PBI, Ringsted, Denmark). Samples were drawn through septa with a syringe to prevent gas leakage.

Changes in quality attributes were also evaluated at 0, 7 and 14 d of storage at 4 °C.

Weight loss (%) was calculated as: $100 \times (FW_0 - FW_t)/FW_0$ where FW_0 is the fresh weight at d 0 and FW_t is the fresh weight at d 7 or 14.

Color was measured using a Minolta Chroma meter (model CR-200, Minolta Corp.) and expressed as lightness (L*), chroma (C*), and hue angle (h°). Color was measured on the top and on the peduncle of florets.

In the florets juice the titratable acidity and soluble solids were determined. Titratable acidity was determined by titration with a solution of sodium hydroxide 0.1 mol L^{-1}, up to the point of phenolphthalein turning, and expressed as g L^{-1} of citric acid. Soluble solids were measured using a digital refractometer with automatic compensation for temperature (model Brix PR-1, Atago CO., Ltd, Tokyo, Japan) and expressed as %. The dry matter content was obtained by drying samples in a thermo-ventilated oven at 70 °C up to constant weight.

2.5. Individuation and concentration of glucosinolates

The glucosinolates (GLS) were extracted according to Kiddle et al. (2001) with slight modifications. Freeze-dried samples (40 mg) were put into 2 mL screw-cap microtubes with 1 mL of 70% methanol at 70 °C for 15 min using a heating block, with regular vortex mixing. The extracts were microcentrifuged (17,500*g* for 10 min at 4 °C) and the supernatants were desulphated on an anion exchange resin. For resin columns preparation, 500 μL of a slurry of DEAE Sephadex A 25:2 mol L^{-1} acetic acid (1:1, v/v) were added to a microtube, centrifuged and the supernatant was discharged. The resin activation was performed by adding 1 mL of 6 mol L^{-1} imidazole formate. The resin was

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