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Effect of UV-C radiation and fluorescent light to control postharvest soft rot in potato seed tubers

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ABSTRACT

Wet rot due to *Pectobacterium carotovorum* subsp. *carotovorum* is one of the main bacteria diseases that affect all potato cultivars causing significant losses. Potato plants contain glycoalkaloids being α-chaconine and α-solanine the main. The accumulation of these glycoalkaloids can be stimulated by several factors, especially light, having them important antimicrobial properties. The aim of this research was to evaluate how postharvest exposition to ultraviolet C (UV-C) and fluorescent light affects the development of *P. carotovorum* soft rot as well as the accumulation of α-chaconine and α-solanine, sprouting, weight loss and soluble solids content in potato seed tubers 'Agata' and 'Monalisa'. Susceptibility of *P. carotovorum* to UV-C light was first *in vitro* tested. For that, bacterial aliquots (10^7 CFU mL^{-1}) were grown in Petri dishes (culture medium YDC) and subjected to 0.0, 2.3, 6.9, 11.5 or 34.5 kJ m^{-2} of UV-C (254 nm) and stored at 25 °C in darkness. Number of colonies was counted after 24 h. For *in vivo* analysis, potato seed tubers were subjected to UV-C (34.5 kJ m^{-2}) with subsequent storage of half of the samples in darkness and the other half under fluorescent light (photon flux of 1.6 μmol m^{-2} s^{-1}) at 25 °C and 88% RH during 21 days. Development (incidence) and severity of wet rot, concentration of α-chaconine and α-solanine, sprouting, and quality parameters were analyzed. Non UV-C treated tubers were used as control. UV-C light at 34.5 kJ m^{-2} completely inhibited the development of *P. carotovorum* subsp. *carotovorum* in *in vitro* studies. For *in vivo* experiments, the control and the UV-C treated tubers stored under fluorescent light were less affected by soft rot than the UV-C treated stored under darkness since any disease incidence was detected on them. Control and UV-C treated tubers stored under fluorescent light as well as UV-C tubers kept in darkness showed an increased concentration of α-chaconine and α-solanine for both cultivars. The largest amount of these glycoalkaloids had an effective influence on controlling soft rot. These tubers also showed highest sprouts number, increased weight loss and soluble solids content. The use of UV-C, firstly reported here, and fluorescent light are advantageous to control soft rot without adversely affecting sprouting.

1. Introduction

The potato (*Solanum tuberosum* L.) ranks fourth among the most important food crops in the world, with a production of 324 Mt (FAOSTAT, 2013). Typically the potato tubers used as seeds for planting present dormancy immediately after harvest, which can be spontaneously broken after a maturation period under favorable environmental conditions (25.0 ± 1.5 °C, and relative humidity (RH) of 85 ± 5%). In addition, the overcoming of dormancy can be achieved by the application of exogenous growth regulators before planting (Finger et al., 2011).

Soft rot caused by *Pectobacterium carotovorum* subsp. *carotovorum* is a major postharvest disease affecting potato cultivars conferring to the tubers a watery aspect, staining brown to black and an unpleasant odor. Dried lesions are presented as blackish marks. Bacterial contamination can occur both in the field and after harvest. Infection may happen at any stage of postharvest handling, including washing and packaging. Temperatures between 25 and 30 °C, with RH above 80%, are extremely favorable conditions for disease development (Czajkowski et al., 2011; Yangui et al., 2013). Chemical control of potato tubers soft rot is the most widely used, including copper oxychloride, copper hydroxide, cuprous oxide,

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copper sulphate (alone or combined with hydrated lime), and some antibiotics like oxytetracycline (alone or combined with streptomycin) and kasugamicina chloride. This type of control, in addition of being expensive, presents the risk of the development of bacteria resistance and environmental contamination. Other control types that avoid those problems have been studied, as heat treatment, ultraviolet radiation and ozone (Czajkowski et al., 2011; Yangui et al., 2013; Ngadze et al., 2014).

Potato tubers contain two naturally occurring glycoalkaloids, α-chaconine and α-solanine, which comprise over 95% of the total glycoalkaloids present in the potato plant (Vorne et al., 2002; Mäder et al., 2009). These glycoalkaloids can be found in all parts of a potato plant and, among the tissues, the periderm and sprouts present the highest concentrations (Finger et al., 2011; Ha et al., 2012). Glycoalkaloids content can vary greatly in different potato cultivars and the biosynthesis of glycoalkaloid can be rapidly stimulated by environmental factors such as light, mechanical injury, storage temperature, diseases and insects (Griffiths et al., 1998; Percival, 1999; Högy and Fangmeier, 2009; Nenaah, 2011).

Simões et al. (2004) reported the antifungal action of α-solanine on *Trichoderma virile*, *Helminthosporium carbonum*, *Fusarium caeruleum* and *Cladosporium fulvum* while Fewell and Roddick (1997) observed the antifungal action of α-chaconine to control *Alternaria alternata* and *Phoma brasicola medicaginis*. Moreover, Silva-Beltrán et al. (2011) reported a reduction of *Escherichia coli* (O157: H7) and *Salmonella* spp. populations in water containing α-chaconine and α-solanine extracts.

UV-C light (254 nm) can be used as a disinfectant postharvest treatment for controlling microbial growth (Koutchama et al., 2009). As advantages, UV-C radiation is not a thermal method and does not form toxic byproducts during treatment. Moreover, it can remove certain organic contaminants, while does not produce odor (Keyser et al., 2008).

The UV-C radiation can still promote the synthesis and accumulation of antimicrobial compounds, induces changes in the cell wall, and increases the activity of antioxidant enzymes, as well as the synthesis of antioxidant molecules, reducing the deterioration rate of fruits and vegetables (Escalona et al., 2010; Martínez Hernández et al., 2011; Pongprasert et al., 2011; Shen et al., 2013). Brown et al. (2001) observed the resistance induction to *Xanthomonas campestris* pv. *campestris* after UV-C application on cabbage seeds. For Obande et al. (2011) UV-C prolonged shelf life in tomatoes and reduced the population of *Penicillium digitatum*. According to Artés-Hernández et al. (2010) UV-C reduced the population of psychrotrophic, mesophilic and enterobacteria in minimally processed watermelon. Filippini et al. (2012) observed that UV-C showed a low survival for *Fibrella aestuarina* and *Spirosoma lingual.* Some authors (Ranganna et al., 1997; Allende et al., 2006; Zhao et al., 2013) reported that the use of ultraviolet radiation inhibited the development of *P. carotovorum* subsp. *carotovorum* in potatoes and other vegetables during storage. Xiadong et al. (2008) showed that UV-C can induce the synthesis of resveratrol in the periderm of grape berries. Despite the positive changes promoted by UV-C some undesirable effects may occur, including skin discoloration in tomato (Liu et al., 1993), browning in strawberries and papayas (Marquenie et al., 2002; Cia et al., 2007), increased susceptibility to brown spot in peaches (Stevens et al., 1998) and acceleration of ripening and senescence in mangoes (González-Aguilar et al., 2001).

The aim of this research was to evaluate the effect of UV-C light in potato seed tubers 'Agata' and 'Monalisa' applied prior to storage under darkness or fluorescent light to control soft rot. Subsequently, its effects on the concentrations α-chaconine and α-solanine, sprouting, weight loss and soluble solids content were also analyzed.

2. Material and methods

2.1. Potato cultivars

Among the potato cultivars worldwide used for cooking and baking, 'Agata' and 'Monalisa' are the most relevant. 'Agata', obtained by Svalöf Weibull AB in 1976 (Netherlands) results from crossing 'Böhn 52/72′ with 'SIRCO'. 'Monalisa', obtained by FGvd Zee & Zonen & Z.P.C. in 1982 (Netherlands) results from crossing 'Bierna A1-287′ with 'Culm' (Wageningen, 2013). Morphological characteristics of potato tubers 'Agata' and 'Monalisa' are presented in Table 1. Tubers were obtained from a local market placed in Cartagena (Spain), and they came from Picardy Region (north of France).

2.2. Bacteria strain

An active culture of *P. carotovorum* subsp. *carotovorum* strain 225T grown in YDC culture medium (Colección Española de Cultivo Tipo – CECT) was used as the source for *in vitro* studies and for tubers inoculation.

2.3. Potato tubers sanitization

Seventy-two tubers of each cultivar were sanitized according to Rocha et al. (2012). The tubers were washed with a solution of tap water and detergent (5%), rinsed with distilled water, disinfected in an aqueous solution of sodium hypochlorite (2%) for 3 min and rinsed with sterile distilled water. After the rinse they were put in trays lined with filter paper and exposed to a 2 h drying process in an oven with forced air ventilation (Digitronic poupinel, Selecta, Barcelona, Spain) at 25 °C in darkness.

2.4. Equipment for UV-C application

The UV-C equipment consisted of two batches of 15 reflectors with unfiltered germicidal emitting lamps (254.7 nm, TUV 36W/G36 T8, Philips, Amsterdam, Netherlands) fixed to a chamber frame. One batch was horizontally suspended on the top of the radiation chamber and the other one was placed bottom of it. Depending on the experiment, the Petri dishes or the potatoes seed tubers were placed between both lines of UV-C lamps (15 cm of distance) over a polystyrene net supported by a steel frame which minimize blockage of UV-C radiation (Artés-Hernández et al., 2009).

Treatment chamber was covered with a protective reflecting inner layer that enhanced homogeneous distribution of the emitted radiation and allow its reflection illumination of practically all sides. In order to determine the UV-C radiation intensity of the lamps and to verify the influence on blockage of the polystyrene net, a VLX 254 radiometer (Vilber Lourmat, Marne la Vallée, France) was used. The applied UV-C intensity was calculated as the mean of 18 UV-C readings on each side of the net. Thus both sides received the same UV-C intensity.

2.5. In vitro

P. carotovorum subsp. *carotovorum* was cultivated in Petri dishes with YDC culture medium (10 g yeast extract; 20 g – glucose; 2 g – $CaCO_3$; 15 g – agar; distilled water – 1 L). To check the *in vitro* effect of UV-C radiation on *P. carotovorum* subsp. *carotovorum* plating of 50 μL aliquots was done with a 10^7 CFU mL^{-1} concentration on YDC culture medium. After exposition to 0, 2.3, 6.9, 11.5 or 34.5 kJ m^{-2} UV-C doses with a flow density of 3.83 mW cm^{-2} at 254 nm the Petri dishes with the bacterial suspension were stored in an incubator (Mermmert, Schwabach, Germany) at 25 °C in the absence of