Postharvest Biology and Technology 111 (2016) 205–208

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

The efficacy of potassium sorbate-coated packaging to control postharvest gray mold in raspberries, blackberries and blueberries

Maria Paula Junqueira-Gonçalves[a,*], Erica Alarcón[b], Keshavan Niranjan[c]

[a] Department of Food Science and Technology, University of Santiago, Chile. Ecuador 3769, Estación Central, Santiago, Chile
[b] Department of Chemical Engineering, University of Santiago, Alameda 3363, Estación Central, Santiago, Chile
[c] Department of Food and Nutritional Sciences, University of Reading, Whiteknights, P.O. Box 226, Reading RG6 6AP, UK

ARTICLE INFO

Article history:
Received 10 September 2014
Received in revised form 11 September 2015
Accepted 11 September 2015
Available online 20 September 2015

Keywords:
Active packaging
Botrytis cinerea
Fresh berries
Shelf-life
Potassium sorbate

ABSTRACT

The aim of this work is to build on the success of *in vitro* studies of an active packaging, produced by coating the surface of post-consumer recycled polyethylene terephthalate (PCRPET) package with an aqueous silicone solution (2%, v/v) containing an antifungal agent (potassium sorbate, KS). Antifungal efficacy was evaluated, *in vivo*, during the storage of raspberries, blackberries and blueberries by examining their shelf life extension. The packaging effectively delayed the growth of *Botrytis* by extending its lag-phase, which, in turn, extended the shelf life of the berries by up to 3 d. Among the three berries tested, the packaging proved to be more advantageous in the case of raspberries, due to their physiological characteristics and shorter shelf life. Based on sensory panel evaluations, it was shown that the coating, containing KS, did not influence the packaging appearance and transparency, and the fruit did not suffer from any off-flavor development.

1. Introduction

There is a growing and impressive evidence base for the health benefits of fresh berry consumption (Tulipani et al., 2008). Berries are a rich source of a wide variety of non-nutritive and bioactive compounds such as flavonoids, phenolics, anthocyanins, phenolic acidsas well as nutritive compounds such as sugars, essential oils, carotenoids, vitamins, and minerals (Nile and Park, 2014). However, a common problem with berries is their high perishability due to rapid ripening and senescence, which hampers storage and marketing (Han et al., 2004). The postharvest life of berries is also determined by their susceptibility to water loss, softening, mechanical injuries, but primarily by the postharvest diseases of gray mold and Rhizopus rot (Reddy et al., 2000; Perkins-Veazie et al., 2008).

Gray mold, caused by *Botrytis cinerea*, is the most important postharvest disease in berries, and has a considerably adverse economic impact. This mold is responsible for significant loss, both before and after harvest, and is a major obstacle to long-distance transport and storage because it can grow at temperatures as low as −0.5 °C and spreads rapidly by means of aerial mycelium among the berries (Crisosto and Mitchell, 2002).

Polyethylene terephthalate (PET) is the most commonly used packaging material, worldwide, for marketing berries. In order to minimize polymer waste the use of recycled PET is increasing (Dimitrov et al., 2013).

Junqueira-Goncalves et al. (2014) described the development of an active packaging designed with post-consumer recycled polyethylene terephthalate (PCRPET) and incorporated potassium sorbate (KS) as an antifungal agent to fight *B. cinerea*. The mechanical, thermal and optical properties of the packaging material were evaluated and its efficacy against *B. cinerea* was demonstrated by employing a novel methodology that mimics actual food contact conditions.

The aim of this work was to confirm the promise indicated in the earlier *in vitro* studies and evaluate the antifungal efficacy of the potassium sorbate-coated packaging, *in vivo*, during the storage of raspberries, blackberries and blueberries.

2. Material and method

2.1. Materials

The polymer used in this study was PCRPET (Typack S.A., Chile), approved by the FDA (Food and Drug Administration) to be in contact with fresh fruits coated with KS (Prinal, Chile) as the

* Corresponding author. Fax: +56 2 27764796.
E-mail addresses: mpaula.junqueira@usach.cl, mpaulaj@hotmail.com (M.P. Junqueira-Gonçalves).

http://dx.doi.org/10.1016/j.postharvbio.2015.09.014
0925-5214/

Table 1
Summary of the fruit origin and trial conditions.

Fruit	Origin	Year of harvest	Storage temperature	Storage time	Place of the analyses
Raspberries	Chile	2012	10 °C	11 d	Chile
	Spain	2013	5 °C	7 d	England
Blackberries	Mexico	2013	5 °C	23 d	England
Blueberries	Chile	2012	0 and 10 °C	28 d	Chile
	Chile	2013	0 °C	49 d	Chile

antifungal agent. The raspberries, blackberries and blueberries employed were standard export quality, from different origins (Chile, Spain and Mexico) and harvested in different years (2012 and/or 2013). These were delivered by two marketing companies, one in Chile (Vital Berry Marketing S.A.) and another in England (Berry World).

2.2. Packaging preparation

The incorporation of potassium sorbate on the surface of the PCRPET was carried out during sheet manufacture by passing it through a bath containing an aqueous silicone solution (2%, v/v) to which KS has been added at a concentration of 20% (w/v). Coating PET with silicone is standard practice in the manufacture of PET packaging, which prevents individual packaging pieces from adhering on high speed manufacturing lines. The addition of KS to the silicone solution imparted antifungal properties to the PET surface, as described by Junqueira-Goncalves et al. (2014), with an active percentage of 0.005%. The sheet was converted to clamshells by thermoforming (John Brown Inc., USA). Some clamshells were also produced from sheets that were only coated with silicone but not KS, and these constituted the control samples.

2.3. Assessment of the shelf life of berries

The fruit (125 g per package) were carefully transferred to the control and active clamshells, and stored in chambers maintained at 0, 5 and 10 °C, simulating temperatures employed during transportation and retailing. Seven replicate clamshells were used for each condition (active and control) and the test was repeated twice.

The efficacy of the potassium sorbate-coated packaging on the berries shelf life was evaluated by the incidence of gray mold-infected berries per clamshell, visually or with the help of magnifying glasses. This test was carried out on the day the fruit arrived at the laboratories after harvest. The specific conditions employed for each fruit study are shown in Table 1.

2.4. Sensory evaluation

A sensory assessment was carried out by a trained panel (who were familiar with the major sensory attributes of good quality berries: taste, aroma, texture and colour of the samples), consisting of 8 women and 3 men, using an unstructured 15-point hedonic scale, where 0 represents the worst, and 15 the best condition, meaning very good or very intense, in order to evaluate the packaging appearance and also its influence on fruit aroma and flavor. The raspberries and blueberries were stored at 5 °C for 4 and 18 d, respectively. These fruits originated from the south of Chile and the storage studies commenced a day after harvest (December, 2012). The samples (125 g) were held at ambient temperature (around 25 °C) 30 min before the test, coded with 3-digit random numbers, and served simultaneously under normal laboratory light.

2.5. Statistical analysis

Experimental values were statistically analyzed by one-way analysis of variance (ANOVA) employing Statgraphics 5.1 software. Differences between pairs of means were assessed on the basis of confidence intervals using the Tukey test. The least significance difference was $P \leq 0.05$.

3. Results and discussion

3.1. Assessment of the shelf life of berries

- Raspberries

The raspberries from the south of Chile were harvested in December 2012 and arrived in Santiago by truck, one day after harvesting. The temperature of transport was less than 5 °C. These fruit were stored at 10 °C for 11 d. The results of the packaging efficacy are shown in Fig. 1.

The raspberries from Spain were harvested in March 2013 and arrived in England by truck, 3 d after harvesting. The temperature of transport was less than 5 °C. These fruit were stored at 5 °C for 7 d. The results of the packaging efficacy are shown in Fig. 2.

In both tests a significant difference ($P < 0.05$) between the control and the potassium sorbate-coated packaging was observed. An extension in the shelf life of the raspberries of 2 or 3 d were observed, especially in the case of the Chilean fruit because they were in contact with the active packaging a few days sooner after harvesting when compared to the Spanish fruit.

- Blackberries

The blackberries were from Mexico, harvested in March 2013 and arrived in England by air freight, 1 d after harvesting. The

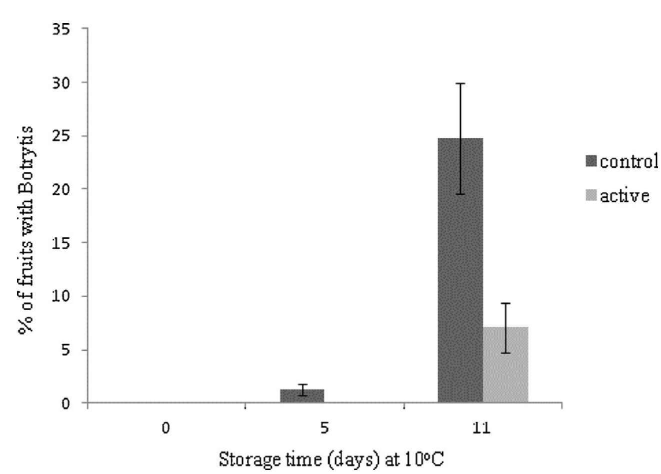

Fig. 1. Percentage of raspberries with *B. cinerea* after storage at 10 °C. Fruit originated from Chile (December, 2012) and packaged 1 d after harvest.